History of Science, Philosophy and Culture in Indian Civilization

General Editor D.P. Chattopadhyaya

Indian Philosophy and Philosophy of Science

SUNDAR SARUKKAI

PHISPC
Centre for Studies in Civilizations

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CENTRE FOR STUDIES IN CIVILIZATIONS

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For
Dhanu

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Sundar Sarukkai

1

INTRODUCTION

This book is about the relevance of Indian philosophy to contemporary philosophy of science. It introduces Indian logic and philosophy of science, as well as some aspects of epistemology and philosophy of language. For quite some time, there have been various claims about the relation between Indian civilisation and modern science. We can identify two broad claims: one is that ancient Indian civilisation had elements of the scientific and the technological, as manifested in their advanced theories in mathematics, astronomy, metallurgy, linguistics and so on. This is a claim that can be verified since there has been substantial documentation on this subject. It is indeed true that Indian society had developed techniques, methodologies and results in fields such as astronomy, mathematics, linguistics and metallurgy, which were much more advanced than in other contemporary civilisations.[1]

The second claim is that some concepts in modern science, particularly in quantum theory and cosmology, are described by and anticipated in ancient Indian thought. This is not only a contentious claim but also one that is untenable or even undesirable. Modern science, particularly quantum theory, is a discourse which is unique in many respects and to claim that some elements of it are actually what the ancient Indian thinkers were talking about is to mistake the nature of both Indian philosophy and modern science.

This book is not concerned explicitly with either of these claims but may have some tangential relevance to them.

It explores the possibility of drawing upon Indian philosophical traditions, particularly its rationalistic ones, to understand the nature and foundations of science. This is what philosophy of science, as a discipline, has accomplished by developing upon ancient and modern Western philosophical traditions. It is surprising that philosophy of science, in its long history, has ignored potential contributions from non-Western philosophies. It will be useful to explore whether Indian rational philosophies have anything to contribute to philosophy of science (and not to science per se).[2]

The success of this exploration will depend on how we understand the nature of philosophy of science: what it does, what it can do and what it is expected to do. This firstly demands an explication of the relation between philosophy and science before we can examine how Indian philosophy can be of any relevance to contemporary philosophy of science. However, before we can consider these issues it will be useful to consider the relation between ancient Greek thought and modern science since there is a strong belief that Greek thought is intrinsically related to science, a position that betrays an unreasonable dependence on Greek philosophy in philosophy of science.

Gadamer, in a series of lectures on the pre-Socratic origins of philosophy, reflects on the origins of philosophy and science in the Greek tradition.[3] The final two essays in this book deal with the relation between Greek philosophy and modern science, and the 'profound debt' owed by modern science to Greek thought. It will be useful to consider his arguments for it might clarify how exactly ancient philosophies are related to modern scientific thought. After summarising his view on this matter, we can then analyse the points of similarity or departure with respect to ancient Indian philosophies.

Gadamer begins with the theme of Greek philosophy and modern thought, a theme that has been a dominant influence on German philosophy over the ages. He notes that Greek

philosophy should not be understood in the restricted sense which defines philosophy today. Greek philosophy not only included scientific thought but, for Gadamer, it was also the Greeks 'who instigated a world-historical decision with their own thinking and decided the path of modern civilisation with the creation of science.'[4] This observation in itself is highly debatable even if we accept that the Greeks created the idea of science, since science in ancient India illustrated great advancement in its times. One can anticipate Gadamer's response to this caveat by noting that his idea of the scientific is subsumed under an idea of the theoretical: for the Greeks, philosophy 'meant the whole of theoretical and, therefore, scientific interest.' It has been an often repeated cliché that Indian thought lacked theory or at least the idea of the theoretical. This comment has been voiced frequently and especially when confronted with ancient Indian technology, including the metallurgical processes of making steel and zinc. Similar comments about the lack of 'philosophy' in India have for long been a part of the Western folklore. I will not respond to these debates, partly because I think some of these sweeping claims have an ideological basis. However, it will be useful to analyse Gadamer's arguments since he is arguing for the essential importance of ancient Greek thought for modern science. What I am trying to do in this book is to argue for the importance of Indian philosophies for philosophy of science.

Gadamer, after noting that Greek philosophy included scientific thought, continues to make the same mistake as many others before him. He writes:

> What separates the occident, Europe, the so-called 'Western world,' from the great hieratic cultures of the Asian countries is precisely this new awakening of the desire to know with which Greek philosophy, Greek mathematics, Greek medicine, and the whole of their theoretical curiosity and their intellectual mastery is associated. Thus, for modern thinking, the confrontation with Greek thinking is a kind of self-encounter for us all.[5]

There are two fundamental mistakes in this claim. First is the emphasis on Asian cultures as being hieratic cultures, namely, cultures that are essentially priestly and concerned with the sacred. There are two reasons why this claim is obviously wrong: one was the living presence of philosophically sophisticated rational traditions of Indian philosophy and the other was the presence of a vibrant scientific and technological culture in ancient India. Secondly, Gadamer compounds this mistake by categorising the difference between the Western world and the Asian one by the 'new awakening of the desire to know'. It is not worthwhile to attempt to refute this obvious absurdity but we can note that Indian philosophy, Indian mathematics, Indian medicine, Indian chemistry and metallurgy, and so on, were all activities that were essentially and intrinsically concerned with the nature of knowing. All the Indian philosophical traditions, including those which are seen to be concerned more with the spiritual, have critical formulations of a theory of knowledge (see Chapter 6 on knowledge in Indian philosophies). Furthermore, the tradition of Indian logic is not only deeply committed to knowing, but also to theoretical formulations of categories such as inference, invariable concomitance, empiricism and so on.

However, what I want to query further is Gadamer's argument linking modern science and Greek philosophy. Greek thought, for Gadamer, exhibits a confrontation 'between the intelligible world and the masterable world.'[6] Galileo is often called the father of modern science. His belief in the mathematical nature of the world as well as his attempts to bring the mathematical together with the empirical influenced the shape of modern science for centuries to come. Gadamer sees this move by Galileo as one that rejects the anthropocentrism that was an essential part of Aristotelian science. Gadamer believes that in the confrontation between modern science and ancient tradition, it is the issue of objectivity that comes to the surface. It is well known that scientific methodology is fundamentally

articulated in terms of objectivity, which includes the possibility of knowing something as an object. To know something as an object is to be able to access it in some particular way. For Gadamer, it is precisely the limits of objectification that is the 'relevant and persistent heritage of Greek thinking.'[7]

Four themes are related to this problem of objectification. The first concerns the body as object. Gadamer makes an interesting point here that Greeks did not have terms for object and objectivity, and even for a 'thing'. The word that referred to all these terms was pragma, which 'refers not to that which stands over against us or opposed to us as something to be overcome, but rather to that within which we move and that with which we have to do.'[8] Gadamer notes that this particular way of viewing the world has been lost in modern science. The second theme is that of freedom, the third is the role of self-consciousness in modern thought and the last is language. Modern thought gives a 'methodological primacy' to self-consciousness, as well exemplified in Descartes' formulation of methodological doubt. However, there is no obvious reason to accept the uncritical acceptance of self-consciousness; Gadamer finds ancient Greek thought a way to critique this uncritical acceptance, thereby finding the limits to self-knowledge. Language is an important theme in this analysis because, among other reasons, language captures the essence of non-objectivity.

Gadamer attempts to find certain points of conflict between ancient Greek philosophy and modern science but in doing so only reiterates the 'enduring relevance' of ancient thought to modern science. In particular, the Greek tradition gives access to a way of integrating the empirical sciences with the praxis of social life. Gadamer is basically dealing with the originary question, going to the origins of Greek thought and finding its relation and relevance to modern thought. And in searching among the ruins of the Greek origins he is doing something that is shared by many other philosophers, particularly philosophers of science. The title of Gadamer's

book—*The Beginning of Knowledge*—is an indication of this argument that traces the origins of particular modes of thought associated with knowledge to the Greeks. It is through this that he finds a common measure of engagement with science, since science is fundamentally concerned with knowledge about the world. The originary question must be important for philosophy of science—at the least to explain why it draws exclusively upon Western philosophy to understand the nature of science. Just as Gadamer's title suggests what idea is to be found in ancient Greek thought, philosophers of science might have as well titled their works—The Beginning of Science—and placed this within Greek thought.

One reason to explain this complete denial of other philosophical traditions in mainstream philosophy of science is based on the belief that modern science is a product of Western civilisation and hence any analysis of it is best done by the philosophical traditions of the same civilisation. This is the originary issue for philosophy of science. This particular point of view is further strengthened by the common observation that natural science grew out of philosophy. However, this observation emphasises common origins of particular kinds of intellectual activities while ignoring the reasons as to why science broke away from traditional philosophy. In the history of modern science, there have been more attempts to show that the distinctive nature of scientific character was radically different from philosophy than attempts to show that they were similar. This is a potential paradox for philosophy of science: it insists on using philosophical insights from traditions whose rejection in the first place catalysed modern science.

There are two kinds of originary questions. One is about civilisational origins, whereby modern science and Western philosophy are in kinship because of common civilisational origins. We have seen the problems with this view. The other is conceptual origin, where there is a common conceptual and methodological space shared by science and some

philosophical traditions. It is obvious that Indian philosophy does not directly have a kinship with modern science as far as civilisation origins are concerned. However, if conceptual and methodological spaces are concerned, there is much in common between Indian rationalist traditions and the practice of modern science. The following chapters map out a few possible links.

Philosophy of science is first and foremost philosophy. It is the act of philosophising about science. To philosophise is to invoke the universe of philosophy to reflect on some subject matter. It is to deploy ideas and concepts from philosophy, to follow certain accepted patterns of argumentation, to explore the meaning of the subject from outside it in some sense and understand its foundations. Philosophy of science thus explores the foundational structure of science. To do this effectively, what kind of philosophy would be most useful? That is, what should be the nature of a philosophy that can best understand science?

There are two possible ways by which we can philosophically reflect on science. We can bring a prior set of philosophical categories through which we analyse science or we can identify some basic concepts in science whose philosophical relevance can then be studied in detail. The latter approach, which is quite common in philosophy of science, would be based upon the fact that science and philosophy (as well as common sense and other non-specialised activities) share a common space, have common concepts and, to some extent, common vocabulary and methodology. However, we need to note that as far as these common concepts are concerned, concepts such as mass, energy, properties, laws and so on, both science and philosophy understand them quite differently.[9]

To philosophically reflect on an idea is to understand the idea through the vocabulary, conceptual structure and modes of argument present in a philosophical tradition. In this broad sense of the meaning of philosophical reflection, there is strictly little relevance for common origins. In principle, say,

we have a scientific idea which we want to philosophically reflect upon. Different philosophical traditions look at the same concept according to the concerns of that tradition. For example, the questions and arguments put forth by the Western phenomenological tradition are radically different from those posed by the Western analytical tradition. Philosophy of science has shown great resistance to incorporating the phenomenological tradition as compared to the analytical one.

The common origin argument for using Western philosophy can also be easily extended to the use of Indian philosophy for the simple reason that science uses and deals with concepts and processes that share a common space with Indian philosophical traditions also. Ideas such as inference, reasoning, knowledge, causality and so on are philosophical themes within Indian traditions as well as in science, and so in principle there is a shared space which allows the first step of philosophising. Furthermore, there are philosophical traditions within the Indian systems which are far closer to certain Western philosophical traditions in comparison with other Western traditions. For example, we could argue that Nyāya is more closer to logical and realist schools of Western philosophy compared to certain idealist and phenomenological traditions in Western thought.

Is there a particular philosophy that is best suited for understanding science? I do not think one can identify any particular tradition or a particular set of ideas as best representing the philosophy of science. Different ideas and different traditions develop more *complex* and nuanced ways of understanding scientific activity. Can there be a philosophy intrinsic to science? It will be very surprising if there is a particular philosophical tradition that best voices science. Realism would be the closest doctrine that one might choose for this role but the complexities of scientific realism actually raises more questions for philosophical debates on realism. Pragmatism is another tradition that is again strongly reflective of scientific practice but pragmatism in philosophy is a much larger system of thought.

Given all these reasons, it seems reasonable to believe that the role of philosophy in science is to reflect upon scientific ideas and practice with the help of certain philosophical tools. Therefore, it seems only reasonable that tools from Indian philosophical traditions should in principle be as important as tools from other Western traditions. After all, not only did the Indians engage actively in scientific and technological issues but they also had a flourishing practice of mathematics and astronomy. Further, Indian philosophy was deeply engaged in the development of disciplines such as logic, epistemology and philosophy of language, where philosophical themes such as empiricism, the nature of inferential reasoning and causality were an integral part.

Philosophy of science, in a most general description, would be 'philosophy in the age of science'. This is because in an age of science philosophy has to respond to the claims and consequences of science. Philosophy of science develops in trying to understand science. Given that both Greek and Indian societies had elements of the scientific in their sense of the term it seems reasonable to believe that a living philosophy in those times would have arisen in response to the issues posed by their sciences. The Indian rationalist tradition embodies one kind of response, one that was concerned with basic problems of empiricism and valid knowledge, while the spiritualist tradition indirectly responded to science through their response to the rationalist philosophies.

The following chapters attempt to establish the validity of my claim that certain aspects of Indian philosophy are not only relevant to a foundationalist description of science but that they also share something in common with scientific methodology. The second chapter begins with the nature of doubt and its relation to science. In Western philosophical tradition, as well as in science, doubt is an important theme. Descartes inaugurated the move towards certain knowledge by beginning with doubt and thus formulated a methodology of doubt. Indian philosophical systems also begin with prioritising the nature of doubt. There is a great deal to be

doubted: our perceptions, reasoning, evidence, inferences and so on. For the Indian logicians, exemplified by the Nyāya school, doubt is the beginning of inquiry. The purpose of inquiry is to resolve a doubt and reach a state of certainty. The Nyāya formulation of doubt is rich in many ways. Doubts are framed in an interrogative form, which in modern terms can be seen as belonging to the 'alternative' type of questions. Doubts are classified into different kinds. Doubt and its resolution are an integral part of the rich tradition of debate in Indian philosophy. The steps to eradicate doubt as part of debate embody a rational strategy, which includes the use of empirical observation, some fundamental principles as also the well-known *nyāya* five-step process, usually referred to as *nyāya* 'syllogism'.

Indian theories of doubt range from the sceptical mode in some Buddhist schools to a pragmatic approach by philosophies such as Nyāya. Descartes' methodology of doubt has been extremely influential in philosophy of science. The Nyāya approach to doubt is pragmatic in nature and is closely related to the relationship between doubt and action. The American pragmatist, Peirce, shares a great affinity with Naiyāyikas (those belonging to the Nyāya school) since his response to sceptical doubt is very similar to theirs. This chapter then discusses the nature of scientific doubt, which is also highly pragmatic in character, and argues how, even in the fundamental description of the nature of doubt, science and Nyāya share similar concerns. The chapter concludes with a brief description of the Indian theories of debate and some important themes in them. This is also of great interest to science because the nature of debate in Indian thought, one that is highly layered in terms of the description of the different types of argument, different kinds of mistakes one can make in a debate and so on, is fundamentally concerned with the possibility of the transition from personal knowing to social knowledge. For science, this shift of knowing from the personal to the social is of paramount importance since it is at the basis of any notion of objectivity. However, I resist

making any facile connections between Indian theories of debate and the rhetoric of science. The approach in this chapter illustrates the thematic contours of a deeper engagement between philosophy of science and Indian philosophy, an approach that will inform and influence the content of this book.

The third chapter is an introduction to some important ideas in Indian logic. The rationalist tradition in Indian thought is essentially related to the logical tradition since logic was about the nature of reasoning, argumentation and the art of persuasion. Indian logic, first developed in ancient times, had a long living tradition, which included important works even as late as the eighteenth century. The greatest contribution to Indian logic came from the Nyāya and Buddhist schools. Inference was the central concern of these logicians. How do we infer? What do we infer? How can we distinguish between a valid and invalid inference? I first discuss an analysis of inference by the early Nyāya school, which then leads to the five-step formulation of *nyāya* method. A qualitative shift in the understanding of inference occurs with the formulation developed by the Buddhist logician Dignāga, whose basic model came to be the standard structure for studying inferences. Dignāga's innovative description of inference was through the notion of 'sign' and he should be understood as exploring the relation between logic and semiotics. After a brief summary of Dignāga's theory, we look at another influential Buddhist logician, Dharmakīrti, whose classification of inference into three types was also very influential. The Naiyāyikas borrowed this system and made some modifications to it. The later Nyāya, called Navya-Nyāya, although continuing this tradition, made some new and important contributions.

After a discussion of these theories of inference, I summarise a few themes from Indian logic which are relevant to philosophy of science. Since the material on Indian logic is not only vast but also quite complicated, the summary of a few salient themes will be helpful to discuss specific points

of interest and contact between some issues in philosophy of science and Indian logic. These themes include a discussion on the differences between Indian and Western logic, induction/deduction structures in Indian logic, the idea of necessary relations which are lawlike, reductio reasoning, the role of fallacies, the meaning of definitions and of properties. In these discussions, we can isolate many common themes from Indian logic that are of potential interest to philosophy of science.

The next three chapters attempt to not just make some connections between Indian philosophy and philosophy of science but also to indicate how these connections could be built upon. First, I consider the various topics that occur in philosophy of science. Chapter 4 can thus be seen as an introduction to some topics in philosophy of science. The first question that is of interest is the relation between science and logic. It is in the character of this relation that we can discover an important distinction between Indian and Western logic, as well as something about how philosophy of science has drawn upon philosophy to understand science.

The relation between science and logic is illustrative of the larger relation between science and philosophy. Philosophy of science, drawing dominantly from the Western tradition, has carefully and extensively discussed the occurrence of logic in science. The history of this engagement clearly illustrates that the primary concern of the early philosophers of science was to show how logic was an integral part of science. This relation between logic and science has filtered so deeply into the social imagination that we normally tend to associate science with logic. But in so doing, it is reasonable to believe that rather than discovering logic in science, philosophy of science may have transplanted logical themes on scientific practice.

In searching for logic in science, philosophy of science has also been guilty of not critiquing its understanding of logic itself. Traditional concerns of philosophy of science have demanded that science be logical. This makes perfect

sense when viewed along the historical trajectory of Western rationalist tradition as well as the growth of logic. However, this is also how Western logic differs markedly from Indian logic. I capture this difference by the use of the phrases 'logic in science' as against 'science in logic'. The fundamental argument that follows is that philosophy of science, based on Western philosophy and logic, is actually searching and demanding for logic in science. In contrast, Indian logicians were demanding that logic be scientific.

It is this question of priority, whether logic comes first or science, that is at the heart of the difference between Indian and Western logic, a difference that is characterised by the question: *Should logic be scientific or should science be logical?* This question might make sense only if we clarify the meanings of the terms logic and science. It is no accident that this naming of something as science or logic has been a serious matter of contention in various debates in the contemporary world. Here, I want to use our common notions of science and logic, and use this to raise the question of priority. If by scientific we mean both an empirical and theoretical mode of reflection, then logic is not scientific for Western logic since the essential character of logic is to be outside the domains of the empirical in an explicit manner. Thus, for Western and modern logic, the issue can only be of the logical in science.

In contrast, for Indian logic, it seems that the central concern was to make logic scientific. This implies that logical statements have to respond to empirical concerns. While this move militates against the very notion of logic in the Western tradition, it is precisely this demand on logic that makes Indian logic essentially correlated to scientific methodology.

Chapter 4 is thus appropriately titled 'Logic in Science: The Western Way'. It describes themes in philosophy of science drawing upon philosophical insights from the Western tradition. Thus, topics such as deduction, induction, Mill's methods, explanation, scientific explanation, definitions and

laws, are dealt with in order to not only give an introduction to these themes but also to clarify areas of enquiry that are common to Indian philosophy and contemporary philosophy of science.

Chapter 5 titled 'Science in Logic: The Indian Way?' begins by asking whether the whole project of arguing that Indian philosophy is relevant for philosophy of science is wrong. Are we trying too hard to fit Indian logic and science? This question becomes important when placed in the contemporary intellectual scene where there is a claim that modern insights were anticipated in ancient cultures. I am explicitly against accepting such claims and the responsibility to carefully argue for these claims rests on those who make these claims. Conscious about this problem, I first begin by arguing that science continues to make 'simple' inferences of the kind that logic, particularly Indian logic, dealt with. A question commonly encountered is: How can examples from ancient Indian logic matter to science today? The simple answer is that there are numerous inferences in science that are conceptually similar to those ancient examples, as well manifested in Newton's laws themselves.

There is yet another common concern of Indian logicians and modern science. This has to do with something foundational about the activity of science. Indian logicians had two great worries: one, the relation between the sign and the signified, and two, the possibility of moving from an observation to saying something about it. The first question is the foundational question of semiotics. And the person who was such an influence in the study of semiotics and its relation to logic was Peirce, the same person whose views on doubt resonated with that of the Naiyāyikas. For both the Indian logicians and Peirce, logic and semiotics were essentially related. Indian logic privileged the notion of a 'natural' sign, or a sign which has some necessary connection with the signified, whereas in the Western tradition the arbitrary nature of the sign became extremely influential. This influence is clearly seen in the way both

mathematics and logic became dependent on the idea of arbitrary symbol.

The Indian logicians were aware of the idea of arbitrary symbols. For Nyāya, a word has an arbitrary relation with the signified. But a logical sign for them was one that had to stand in a 'necessary' relation with what it stood for. The equivalence of sign, reason and evidence in Indian logic is also symptomatic of this emphasis on a necessary relation. If we believe that something represents something else, then what is the reason for such a belief? This is the question that bothered these logicians and their complex formulations for invariable concomitance is a reflection of the difficulty in finding such necessary and universal connections. This challenge of defining the idea of necessary relation is also one that occurs in the analysis of scientific law.

Not only is Indian logic a matter of semiotics, so also is science. The semiotic character of science is not often discussed. However, there is much in science that is played out through the language of semiotics. We need look no further than interpretation of experimental observations, where we see a mark that stands for something else as evidence for the existence of an entity or phenomenon. Since science extends observation into the domain of instruments, we need to learn what the instrument is 'seeing' based on its output. From an experimental observation, how can we be sure that the mark or sign does indeed refer to a particular entity, for example, an electron? Dignāga gave three conditions for a sign to be a logical sign. If we extend this question into the semiotics of experimental observation, we can easily see that Dignāga's conditions of similarity and dissimilarity cases do the same work as the demand in science for replicability of experiments and the importance of null-results.

The other fundamental concern for Indian logicians—the validity of making generalisations from observations—indicates the problem of moving from experimental observation to theorising about them. Generalisation is a

common and important step in theory formation. Some observations can be generalised and others cannot. Why is this so? What kind of evidence allows generalisation? While these are questions that overlap with the problem of induction, the Indian approach to these questions differs in significant respects. I argue that this issue of the experiment–theory link in modern science shares common conceptual problems with Indian logic. Thus, we find a rich interface between Indian logic, semiotics and science.

This chapter concludes with interpreting Indian logic along the model of explanation. It is clear that the Indian logical structure is fundamentally concerned with explanation. The differentiation of inference into inference-for-oneself and inference-for-others also makes this explicit. Now, what seems interesting is that the Indian logical structure is not just any theory of explanation but one which matches very closely with the structure and aims of *scientific explanation.* The early *nyāya* five-step process has a strong correlation with the deductive–nomological model of scientific explanation. The Buddhist reworking of the inferential model is also concerned with generating explanation of the relation between generalities. The connection between Indian logic, semiotics and scientific explanation shows once more the close connection between the concerns of Indian logic and what we call as scientific methodology today, thus reiterating once more that demanding logic to be scientific is probably a more faithful description of science as compared to the belief that science should be logical.

The final chapter deals with the question of knowledge. Science and philosophy both have a strong engagement with various issues of knowledge, including what constitutes valid knowledge, how scientific knowledge is distinguished from other kinds of knowledge and so on. Indian philosophy has a rich tradition of epistemology. All schools held a theory of knowledge, called *pramāṇa* theory. What varied between them was the number and type of *pramāṇas,* the means of valid knowledge. The *pramāṇa* theory has been described as a

causal, reliabilist theory, a clue to which is already present in the understanding of *pramāṇas* not only as justificators but also as causal agents of knowledge. If we look at what characterises scientific knowledge, we are not far off from a causal, reliabilist model. This similarity should not be surprising given that empiricism is the ground for both Nyāya and science. Further, the notion of truth is fundamental to science. For Indian theories, truth has been described in various ways, somewhat similar to the correspondence, coherence and pragmatist theories of truth in Western philosophy. I discuss in detail one aspect of truth that has been of great influence in Nyāya and also in science. This is the relation between truth and action.

The final theme for exploring common ideas in Indian philosophy and science is that of language. Philosophy of language is one of the original pillars of Indian philosophy and the great expanse of themes within it is indeed remarkable. With the same spirit that informs the remainder of the book, my brief discussion of language is more to suggest what can be done rather than a description of how they can be used in philosophy of science. One issue that I discuss in detail however is that of effability, a thesis that has strong proponents among the Nyāya and the grammarian Bhartṛhari. The effability thesis is the view that everything knowable is expressible in language. There is nothing in the world of knowledge that is outside the capacity of language. For Bhartṛhari, effability is made possible by an extremely interesting theory of words, sentences and their meaning. It is also dependent on a natural connection between words and their meaning at a fundamental level of consciousness.

For science, effability is given in the belief that there is no knowledge about the world which cannot, in principle, be accessed by science. In fact, as I have argued elsewhere, the use of multiple semiotic systems in scientific discourse, including mathematics, the continued creation of new sub-disciplines of mathematics and appropriation of concepts from them to describe the world, point to a

fundamental belief that drives the activity of science: to understand the world is to understand its language.[10]

The belief that mathematical concepts have a special correspondence with physical ideas has been enshrined in the popular phrase, 'the unreasonable effectiveness of mathematics'. The claims that mathematics is the correct language of the world and that there is a natural relation between mathematical concepts and the world have a striking resonance with Bhartṛhari's thesis. The task of science is therefore to find all the correctly matching mathematical 'words'. This belief about mathematics is a statement about effability in science of the Bhartṛharian kind. Thus, the locus where Indian theories of language meet modern science, and particularly applied mathematics, is one that can generate profound, new insights into the nature of both language and science.

There is much that I have not discussed in this book. Indian philosophy is a vast ocean as is science. My focus on the rationalist tradition in Indian thought, including Indian logic, is very selective and drawn extensively from pioneering translation and interpretation done by philosophers such as Matilal and Mohanty. Needless to add, without their toil this book would not have materialised. I do not cover Vedānta and its relation to modern science. There has been a lot written on this relation and although I am tempted to redraw the boundaries of this relation it will have to wait for another time and another place. It will also be clear in reading this book that there is much less use of Sanskrit words and terms that usually fill a good part of a text in Indian philosophy. There are many reasons for consciously using these words minimally and only when required, one of which is that I believe we have reached a stage in Indian philosophy which allows us to work with its ideas without making this constant referral to Sanskrit words, a lesson that is usefully learnt from what Western philosophy has done in avoiding the excessive use of Greek or German words, a move which has aided in the establishment of a flourishing, living tradition

of Western philosophy. In this book, I have tried to be sensitive to the claims of traditional knowledge but at the same time I have also tried to suggest possible themes in these traditions which can be critiqued and expanded. Although through the length of this book I am constantly suggesting how Indian philosophical themes are relevant to philosophy of science, I also hope that this is one way of getting Indian philosophy to engage with and respond to ideas and challenges from various other traditions, including Western philosophy and modern science.

2

DOUBT

Science begins from doubt just as knowledge begins from doubt. That the origins of knowledge lie in doubt has been widely accepted in different philosophical traditions. The theme of doubt has been very influential in the Western tradition, as particularly exemplified in Descartes' methodology of doubt. Along with his other contributions, his analysis of doubt has served to enshrine the theme of doubt as an important element of scientific spirit and methodology. In the Western tradition, his reflections on doubt have had a profound influence. Descartes moved towards scepticism through doubting everything. This kind of universal doubting actually reflects a method of doubt. For Descartes, the method of doubting was a way to achieve certain and indubitable knowledge. This process of continued doubting came to a natural end when he realised that he could not further doubt his own doubting. Building from this observation that there can be some foundational beliefs that cannot be doubted, Descartes thought he could build a system of knowledge based on firm foundations. With his method of universal and hyperbolic doubt, Descartes attempted to find foundations for knowledge, foundations which themselves are not in need of further foundations. Foundational basis for knowledge is possible when built from a set of basic beliefs which we are certain of and which need no further foundations.

Descartes' analysis of doubt is problematical for various reasons.[1] Peirce's critique of Descartian doubt, a critique

which shares a great similarity with the Nyāya view, is closer to the scientific response to the notion of doubt. I will discuss these formulations of doubt in greater detail below. In the Indian tradition, doubt (*samśaya*) has played a seminal part in philosophical discourse. Three particular problems related to the idea of doubt have generated extensive literature and are also relevant to the concerns of this book. They are exemplified by the Buddhist, Nyāya and Vedāntic approach to the problem of doubt. In the Buddhist tradition, we can see a sceptical approach to doubt, while pragmatism informs the nature of doubt for the Naiyāyikas. Advaita Vedāntic notion of doubt points out to the larger problem of illusion and reality, and doubts relating to our knowledge of the real. All the traditions prominently consider the theme of error in the context of their discussions on doubt.

The Buddhist philosopher Nāgārjuna (c. 150 AD) illustrates a brand of scepticism which questions the possibility of foundational beliefs upon which knowledge can rest. This attitude towards foundationalism is found in his critique of the *pramāṇa* theory, the predominant theory of knowledge in Indian philosophy (see Chapter 6). According to this view, knowledge is based on some *pramāṇas*, which are means of valid knowledge. Nāgārjuna critiques this view by arguing that the *pramāṇas*, which are the foundation of knowledge, themselves need validation. If every piece of knowledge can be based upon some *pramāṇa*, then what is the *pramāṇa* itself based upon? Matilal notes that if we accept a more general characterisation of scepticism then Nāgārjuna can indeed be seen as operating within the sceptical mode when he critiques the possibility of foundations of knowledge.[2] In so doing, Nāgārjuna, like the later Advaita-Vedāntin sceptic, Śrīharṣa, (c. 1000–1100 AD) suggests that if we accept any means as the basic foundation for knowledge, then we have to have reason, that is further foundations, on which these foundations rest. Or we would at least need to know why such foundations are not necessary. Rather than enter into the debate on scepticism, we can note another

kind of response, one that Śrīharṣa takes when he argues that the job of the sceptic is only to challenge the presuppositions of the opponent in a debate and not to give alternate answers to his own question.[3]

However it is arguable whether science exhibits a sceptical nature of doubting. Science has a more pragmatic view on the nature of doubt. There is a description of doubt in Indian thought which shares concerns similar to those expressed by scientific doubt. This is the approach to doubt by the Nyāya school.

2.1 *Nature of Doubt: Nyāya*

The very nature of doubt potentially leads to infinite regress. We can always doubt answers that are given to a doubt. However, the Naiyāyikas would argue that we are mistaken about the fundamental nature of doubt if we think we can doubt everything. While it may seem to us that we can indeed doubt every statement, these are not 'real' doubts. There are conditions under which doubt occurs and also reasons for doubting. There is no doubting in vacuum nor is it the 'default' condition of cognition.[4]

The Nyāya theory of doubt manifests the importance of the idea of doubt in Indian philosophy. Understood within the larger framework of Indian philosophical systems with their deep concerns about mistaken conclusions one routinely makes, Nyāya theory of doubt can be seen as one element in the development of a rational philosophy of the world and our relation with it. While this theory deals with some standard issues of doubt that largely deal with perception, inference and testimony, it also discusses various concepts that are part of a larger realist discourse, including the notions of uncertainty, indeterminateness, conjecture, practical action, foundationalism and so on.

First of all, doubt is a mental process which is a judgement. Cognitive judgements are of two types: true and untrue.[5] Therefore, in this view there are true cognitions and false

cognitions. There are three kinds of false or untrue cognitions: doubt, error and *tarka* (suppositional reasoning or *reductio ad absurdum*; see Chapter 3 for a detailed discussion of *tarka*). We can understand doubt as the recognition of the possibility of error. Recognising the error in itself is eradication of doubt. Doubt is one of the sixteen categories described in *Nyāyasūtras*, the text of early Nyāya. The process of inquiry begins with some initial doubt, about a particular thesis or reason or perception. The remaining steps are the method that will resolve this doubt and lead us to a state of certainty.

According to Nyāya, once a state of doubt occurs the steps that are needed for the resolution of that doubt are: purpose, observational data, doctrinal bases, the schema of the argument, *tarka* or suppositional reasoning and decision.[6] Purpose is the intended goal in the inquirer's mind. The specific doubt that occurs is dependent on this final goal or purpose of the inquiry, thus suggesting the impossibility of doubt for the sake of doubt. Knowing the purpose and the nature of doubt, the philosopher then needs some basis upon which to proceed. Underlining the realist, empirical nature of Nyāya, the next step in the resolution of doubt is to draw upon the set of observations and examples. Along with this, certain doctrinal principles are also used and these are classified into four headings. Matilal suggests that these are similar to *a priori* principles, although we need to use the term *a priori* with various qualifications. The basic point here is that it is not possible to resolve a doubt, even when the purpose is known, if there is no ground upon which to proceed. Empirical observations as well as some general '*a priori*' principles are the grounding which help us eradicate doubt.

The next step in this process is to reason using the observations and principles. Nyāya offers a well-known structure of argumentation, which is a five-step process that explains a particular inferential conclusion. This method of argumentation, the standard mark of early Nyāya, will be discussed in more detail in the next chapter. After the use of

this structured reasoning, we can employ *tarka* and finally the philosopher who began with a doubt reaches an indubitable conclusion. These steps are those that eradicate doubt but do not constitute a *method* of doubting as Descartes meant it.

As far as this is a necessary way of proceeding to resolve doubt, we can see an immediate connection with scientific methodology, which moves from hypothesis to result based not only on empirical observations but also on general principles and laws. Later on in this chapter, we will see whether we can build on what at this point is only suggestive similarity.

2.2 *Contrastive and Theory-laden Nature of Doubt*

For the Naiyāyikas, unless there is some prior doubt there is no possibility of initiating some inquiry (although there is an exception that has to do with a special desire to infer even when there is no doubt). Correspondingly, at the other end, unless there is some prior 'knowledge' there can be no doubt. Doubt does not arise in a vacuum; it arises not only in response to some confusion but is also based on some prerequisites, which includes not only this prior 'knowledge' of something that leads to doubt but also the absence of universal scepticism. In philosophy of science, the theory-laden nature of observations is the view that observations make sense only when interpreted according to some prior theory. The argument that doubt does not arise in a vacuum and needs prior background knowledge for its articulation suggests the essential theory-laden nature of doubt.

Typically, statements of doubt are of the form: 'Is S p or q?' We may ask why a statement of the form 'Is S p?' not indicative of a doubt. For Nyāya, doubt has two 'essential components': one, predicates such as p and q that arise in the doubt must be mutually incompatible and two, they must refer to the same subject, namely the same S.[7] That p and q are incompatible means that one is never present in the

locus of the other. Even in later formulations of doubt, this two-predicate structure of doubt is retained. Later Naiyāyikas described the 'incompatibility' in other ways also. For example, as one being a hindrance to the other and expressed by their relative strengths. Vardhamāna points out that the essential character of doubt lies in the 'oscillation' between these p and q. Consider this common example used by Nyāya: We see an object in the distance and have a doubt as to whether it is a man or a post. Obviously, the object cannot be both man and post. So, an important characteristic of doubt, in this example, seems to be the capacity to imagine alternatives in the judgement of a perception. Ganeri notes that the conditions to imagine two possible alternatives is a necessary condition of doubt. Thus, he goes on to add, the 'limits of imaginary supposition are the limits of doubt.'[8]

So, it seems that the Nyāya theory of doubt is essentially based not only on the confused or unclear recognition of one characteristic of the subject of doubt but also the recognition of its possibly being something else. A question of the form 'Is S p?' is strictly not a doubt. One way to understand this insistence on two incompatible characteristics that make a question a doubt is by looking at the question 'Is S p?' as a question which demands an affirmative answer. However, it also seems that many of the questions which express doubt make reference only to one characteristic and not two. For example, consider the following single-predicate questions: Is the sky blue? Is the orange sweet? Is that a man? Does the sun go around the earth? Is matter made of atoms? Is gravity the cause of free fall of bodies? It might seem that they all sound like doubt but not so for the Naiyāyikas. We can understand a possible Nyāya response to this problem in the following manner: one, even though we are talking of one predicate we are actually referring to some background information which is not explicitly stated. This also leads us to consider single-predicate doubts as actually being either pseudo doubts or invalid doubts (such as doubt going against action) or imperfectly articulated

doubts. Two, statements of doubt are contrastive in nature. This view is similar to the contrastive view of explanations (see Chapter 4) where we understand explanations as not being answers to questions of the type 'Why p?' but rather to 'Why p instead of q?' Nyāya's emphasis on the contrastive aspect also suggests the possibility that doubt for them is part of a larger explanatory process, a view that will be explored in greater detail in Chapter 5. If the contrastive character is actually an important part of explanation, then contrastive doubt is actually much closer to the way doubt really arises in us.

Moreover, the answer that can be given to a question of the form 'Is S p?' is different from that for a question 'Is S p or q?' The answer to the former is expected in the form of an affirmation or negation, yes or no, whereas in the latter, one of the two possibilities is chosen. The first question is not necessarily asked to resolve a doubt but many times only for confirmation or disconfirmation of one's beliefs about S. In the cases where the answer is in the positive, it is only a reaffirmation of an already held belief and this does not constitute doubt. Similarly for the negative answer. Another way of understanding this is to look at questions of the form, 'Isn't S p?' This form of the question also does the job of re-affirmation or disconfirmation and seems to be 'equivalent' to questions of the form 'Is S p?' Now, it seems difficult to do the same for questions of the form 'Is S p or q?' A doubtful statement such as this does not equivalently translate as 'Isn't S p or q?' The mark of doubt is captured in the use of 'Is S ...' and not 'Isn't S ...'. While we can genuinely doubt 'Is that a man or a post?' we cannot express it as 'Isn't that a man or a post?' A simple example again illustrates this perhaps crucial distinction captured by the use of is and isn't in the case of contrastive questions. For example, we can imagine being in a philosophy conference where, as it always happens in such meetings, somebody is pointing to another and asking a question about the identity of that person. The standard questions using 'isn't' are of the form

'Isn't he Nāgārjuna?' and not 'Isn't he Nāgārjuna or Descartes?' While it would be unwise to generalise to all such questions, this difference might indicate the reasons why the contrastive element in questions is indicative of the state of doubt.

Consider the question 'Is the orange sweet?' For Nyāya, all questions are not automatically possible even though we may be able to verbalise a doubt. There are reasons which cause doubts. One does not suddenly doubt whether this orange is sweet unless one has reason to doubt it. And the particular reason to doubt will be of such a character that it will have the contrastive in it. For example, I look at a green orange and have the doubt 'Is this orange sweet?' Since the origin of the doubt is the colour of the fruit, which I have associated with sourness since green oranges I know are most often but not always sour, I have the doubt about its sweetness. Therefore, if this is the case, the correct doubt should be 'Is this orange sweet or sour?'

It is important to notice that doubt is expressed in terms of a question. The statements of doubt are interrogative sentences. What is the relation between a question and a doubt? What is the implication that doubt be expressed in the form of a question? Are all questions then of a doubtful nature? These and other important issues present in the acts of questioning and answering have not been given their due in an analysis of doubt. It would be useful to consider this dimension of questions and answers in a discussion on doubt. We can draw on substantial work on the nature of interrogatives and on the discursive structure of questions and answers. One very brief intervention along these lines is given below.

We have seen earlier the Nyāya formulation of doubt expressed in terms of a question of the form 'Is S p or q?' This is one type of a question. In analysing the nature of the interrogative, Somerville points out that there are three main types of questions.[9] One type consists of 'yes–no questions', which are questions which have Yes or No as answers. Note

that questions of the form 'Is S p?' belong to this type. The second type are questions which use interrogative words such as what, where, who, how, why and so on. The third type consists of questions called 'alternative questions', which are questions of the form 'Is she coming or going?'[10] We can see that questions of the type 'Is S p or q?' belong to the class of 'alternative questions'. These can be extended to questions like 'Is S p or q or t?' and so on. The Nyāya form of doubt best fits alternative questions. It might seem that yes–no questions are themselves a subset of alternative questions. One of the reasons for this is that a yes–no question such as 'Is S p?' can be written as 'Is S p or not-p?' Therefore, yes–no questions are much more limited than alternative questions since only the contradictory (not-p) is allowed. Somerville notes that there is also a logical difference between these two types of questions because for a yes-no question either p or not-p obtains whereas for an alternative question it can be either p or q, with neither of them being logically connected to the other. This argument only reinforces the point made earlier about distinguishing 'Is S p?' questions from 'Is S p or q?' questions. As we saw there, the latter embody the form of doubt according to Nyāya. More work on the nature of interrogatives in the context of Indian philosophy promises to be fruitful.

2.3 *Types of Doubt*

Nyāya classifies different kinds of doubt and this classification is based on the causes of doubt. There are two types of causes of doubt: general and specific causes. The general causes, reflecting the fact that doubt does not arise in a vacuum, describe the necessary conditions which will allow doubt to appear. The idea of necessary conditions for doubt must remind us of Mill's methods (Chapter 4), especially since the types of doubt are based on types of causes. The general causes of doubt are further divided into positive and negative causes. The positive causes are prior

certain knowledge of the substantive and 'remembrance of the two alternatives.'[11] The first condition is related to the need for certainty of something in order to have proper doubt and in this case it is the knowledge one has of S or 'that S'. That is, to have some doubt about S we need to know that S is really present. The second point refers to a crucial question about doubt. It addressees the problem of why one asks 'Is S p or q?' and not 'Is S u or v?' What is it that allows us to associate the predicates p and q, and not any other predicates, to S? What is it in the nature of doubt that does this? Obviously, doubt qua doubt should be indifferent to whether the predicates are p and q or u and v. Therefore, the fact that we doubt whether S is p or q indicates our memory of these two predicates and their association with S.

Some of the above points also direct our attention to the theory-laden nature of doubt. The analogy from theory-laden observation is useful here. It has been argued in philosophy of science that observations are essentially theory-laden in that we can make sense of observations only in the light of a prior theory we already hold. For example, unless we already had a theory of electromagnetism there was no way that the lines in a cloud chamber photograph could be interpreted as indicating the presence of electrons. This dependence of doubt on prior knowledge, memory and so on makes universal scepticism impossible for Nyāya. The presence of contrastive elements also makes explicit this dependence of doubt on prior knowledge.

Nyāya classifies doubts into four types. These types of doubt also reinforce the contrastive nature of doubt. The four types are as follows: one, perception of common characteristics of both p and q that makes doubt possible. Thus, the doubt as to whether the object is a man or a post arises only because both the man in the far-off distance and the post share some characteristics. The second type explains how doubt arises when an uncommon property is perceived. The third is about doubt arising when we hear two conflicting testimonies and are unable to decide which of the two should

be accepted. And finally the fourth type is about the ontological status of perception, as to whether what we perceive is real or not.[12]

Although the above four types are doubts related to perception, doubt about inference was also an important issue. In inference, there is an extrapolation from a particular observation to a general statement and this extrapolation can be a matter of doubt. When this generality is a pervasion relation, as for example in the smoke–fire relation, then there is always a doubt whether the generalisation is correct. Indian logic illustrates a sustained attempt to achieve certainty about such generalisations. Sceptical doubt negates any possibility of accepting the pervasion relation, since the sceptic can continue to doubt even in the face of all evidence. Doubt can be eradicated only if the individual does not have certain biases which block doubt. For Nyāya, scepticism will be one such bias. An example is the 'excessive love of mother over son', which can block the origin of certain kinds of doubt in her mind about her son. Actually, Nyāya is not concerned about this kind of psychological condition which blocks or enables doubt but is more concerned with *certain conditions of the object* (and not of the subject), which cause doubt, thereby making this approach epistemic and not psychological.[13]

2.4 *Limits of Doubt: Nyāya and Peirce*

Given Descartes' influential views on doubt, a comparison between Descartes and Nyāya theories of doubt will be useful and this is what Mohanty does. However, the Nyāya view is more usefully compared and contrasted with the 19th century American philosopher, Charles Sanders Peirce. It is also much more useful to understand the nature of scientific doubt alongside the Nyāya view. The problems with Descartes' theory of universal and hyperbolic doubt, in contrast to Nyāya, are many. Firstly, such doubting is not authentic doubting but seems to masquerade like doubt. Mohanty makes the

important observation that what essentially distinguishes Descartes' doubt and that of Nyāya is the role of free will. If humans can withhold assent and continue to doubt independent of whether the doubt is resolved or not, then it means that we have the freedom to continue to doubt endlessly. It is precisely this kind of doubt that Nyāya dismisses as being inauthentic, thereby indicating the limits of our capacity to doubt without reason. And this limit is given by practical behaviour and doubt related to that behaviour. Hence, the response by Gaṅgeśa to the sceptical challenge of infinite regress related to suppositional reasoning is to limit doubt by the implications of action. For example, if somebody continues to doubt the pervasion relation between smoke and fire even after all evidence and argument, then if such a person lights a fire when he wants smoke it betrays the fact that his doubt about the necessary relation between smoke and fire is false. Action contrary to the claim of doubt betrays the inauthenticity of the doubt. Further, this is related to habit, a formulation which is not only similar but also central to the pragmatists' worldview. Gaṅgeśa notes that 'when there is doubt, there is no regular pattern of behaviour. When there is a regular pattern, doubt does not occur.'[14] Mohanty notes that this is exactly what Descartes and Husserl did not want: they believed that one could have universal doubt yet continue with normal practical behaviour.

Peirce's arguments against Descartes share much in common with Nyāya's views on doubt. First of all, for Peirce, doubt cannot arise in a vacuum and he phrases this by saying that we 'cannot begin with complete doubt'. There has to be what he calls 'positive conditions' as factors for doubting. He also questions the authenticity of doubt-like statements as being representative of a true state of doubting. Hence his call not to pretend to doubt: 'Let us not pretend to doubt in philosophy what we do not doubt in our hearts.'[15] For Descartes, we can continue to perform an act and yet have doubts related to it. Pierce notes that this is impossible because we act based on our beliefs and when in doubt, we

do not act until the doubt is resolved. As he writes, 'The feeling of believing is a more or less sure indication of there being established in our nature some habit which will determine our actions. Doubt never has such an effect.'[16] (However, note that one can argue that what Descartes is doing is precisely this—to make doubting a habit.) This relation between doubt and action makes doubt context-specific. This does not mean that all the beliefs associated with our action are indubitable. The point for Peirce is that we cannot step outside our world of beliefs when we doubt some of them but will have to work with them and modify them gradually. Further, the kind of universal doubt of Descartes is a psychological impossibility for Peirce especially since he, like the Naiyāyikas, believes in the intrinsic relation between action, conduct and doubt. The pragmatic strain in Peirce is also that found in Nyāya. And finally, what brings Peirce and Nyāya together once again, is his support of fallibilism, the view that no beliefs are known for certain and that all our beliefs are open to change, however much they may look like truth at a particular time. This fallibilist view of Peirce and Nyāya, along with their pragmatic notion of doubt, allows us to understand the nature of scientific doubt (and methodology) in a far more useful manner than by using the Descartian formulation of doubt.

2.5 *The Nature of Scientific Doubt*

It may seem that the idea of doubt is methodologically enshrined in science. But a careful analysis of doubt in science shows many different facets. First of all, there is no universal scepticism in science. The independent reality of the world is a given as also the subject. Nevertheless, doubt is very important in the process of inquiry. The initiation of an inquiry can take many forms. Scientific doubt shares a common space with ordinary doubt, that is, doubt dealing with uncertainty in perception, inference and so on. At one level, there seems to be nothing unique about scientific doubt but

what may be unique to science is the methodology to eradicate doubt. Science's view of doubt, as manifested in its practice, exhibits characteristics such as absence of universal doubt and scepticism, fallibility and emphasis on action and pragmatism. But is there anything more we can say about the nature of such doubts?

I suggest that the Nyāya theory of doubt may be a useful starting point to analyse doubt in science. First of all, doubt in science exhibits many of the characteristics found in the Nyāya view. As mentioned earlier, these have to do with the denial of absolute scepticism, fallibility, emphasis on the link between doubt and action and so on. The link between doubt and action, which for the Nyāya involves an action that negates the doubt in its performance, is manifested in science through experiments and the use of technology. These are elements which uniquely characterise the scientific response to the world. Further, the nature of doubt as described by Nyāya in terms of general and specific causes leading to the classification of types of doubt is also well suited to describing scientific doubt. In particular, the causal origin of doubt is important for science. One reason is its belief that to resolve the doubtful nature of a scientific claim it may be necessary to go to its origins and analyse the cause of the confusion inherent in doubt. In science, we often find that the removal of doubt about something means the removal of the cause of the doubt.

The emphasis on doubt and action is not just related to doubt per se. It is related to a worldview which insists that mere doubt is meaningless unless there are potential ways of resolving it. Mere doubt, doubt for its own sake, is part of the sceptics oeuvre. But if doubts are caused, if doubts are dependent on conditions, if there is a structure to doubt as manifested in its classification into different types, then doubt for doubt's sake is meaningless, mainly because there are clear reasons for the occurrence of a doubt. Once we identify these factors involved in doubt, we are actually identifying what needs to be tackled to resolve the doubt. Thus, unlike

how Mohanty interprets it, the relation between doubt and action is not the inability to theorise about doubt beyond its contingency but illustrates the impossibility of theoretical, non-contextual doubt. To the Naiyāyika, the problem would not be in formulating philosophical doubt per se, but in the impossibility of such a doubt without it being imbued by contingent facts, including those of the empirical and linguistic. This is a view shared by Nyāya and science.

In modern science, doubt manifests itself in various ways. In experiments, there is always a doubt about how we interpret observations and measurement. Since scientific observation is most often mediated by instrumental observation the question of interpretation is extremely important and therefore, so also the question of doubt. Here the role of doubt is crucial because the 'right' doubt can illuminate the meaning of the measurement or observation. Following the Nyāya theory, it is worthwhile asking whether science also manifests different kinds of doubts. The Nyāya classification by itself is not directly applicable to classify the kinds of doubt, although they suggest a kind of conceptual scheme that could be used. As we saw earlier, this involves the use of contrastive predicates, causal origin, specific types of relations between these predicates and so on. In broad terms we can classify doubt in science as doubts associated with hypothesis, explanation, definition, description, interpretation in observation, in the use of mathematical concepts and structures, and so on. The question is whether some of these are themselves different kinds of doubt.

Consider hypothesis. It is well known that scientific development proceeds by proposing hypotheses and testing them for their validity. Now, hypotheses are not proposed in a vacuum. Suppose, as it often happens, there is more than one hypothesis. Does this situation lead to the occurrence of a doubt? At first glance, it does seem so. We have a doubt about which hypothesis is the 'right' one. For the Nyāya, this would mean asking what kind of a doubt this is—does our doubt about two competing hypotheses arise because they

share some similar features, as in the first type of doubt in Nyāya? Since the Nyāya types of doubt are also a classification of the origins of doubt, the equivalent question about doubting hypotheses is as follows: is our doubt about a particular hypothesis based on recognition of similar and dissimilar characteristics? For example, suppose we hypothesise that the sun is moving around the earth instead of the earth moving around the sun. These two hypotheses share some similar and dissimilar characteristics. What is the origin of doubt as to which of these two hypotheses is correct? Do we have a doubt because these share some common similarities, conceptual and observational? Or is it that the doubt arises because of dissimilarities in them? Note that in extending the idea of Nyāya classification we are also extending the provenance of doubt beyond perceptual similarities and dissimilarities.

The crucial difference between scientific perception and ordinary perception is the interpretative structure of observations in science. Doubt arises in us because of particular conditions which impede clarity in perception. For science, indirect perception or rather inference from observations is the normal mode and therefore doubt is strongly associated with such inferential process. Thus, doubt about hypothesis in science is actually similar to the doubt about particular inferences, another similarity with Nyāya. Also, hypotheses are framed in the background of some prior knowledge. Most often, prior theories are needed to formulate new hypothesis—exhibiting once more the theory-laden nature of observations and therefore, the theory-laden nature of doubt itself. As much as doubt, hypothesis also needs conditions which can catalyse their creation.

Yet another kind of doubt in science has to do with mathematical use in theoretical sciences. There are two aspects to this: one, doubt as to whether the correct mathematics has been used and the other doubt as to whether the mathematics has been correctly done. The latter is resolved through methods of proof in mathematics but the

former is resolved only through the success of the theories that result from using new mathematical concepts and structures. In other words, the doubt about particular mathematical structures is removed based on successful action.

Finally, I would like to discuss one important difference in the nature of inquiry as understood by science and Nyāya. For Nyāya, doubt is the initiator of inquiry, which ends with some certain conclusion. Therefore, doubt is important to the larger project of knowledge. Science also privileges doubt and critical inquiry in general as an important component of its methodology leading to the creation of scientific knowledge. However, there is also an important activity in science which generates knowledge without beginning from or perhaps even engaging with the idea of doubt. This occurs most often in the description of scientific discoveries. I will discuss two types of discoveries. These are an essential aspect of the creation of scientific knowledge but they also radically question the fundamental position given to doubt. The first is the case of serendipity where a scientist stumbles upon a discovery without being led to it through methodological questioning. Such discoveries are an accident, however much the accident needs a prepared mind to see the accident for what it is. The other example is discovery through play. I mean to use 'play' in the common connotative sense. There is much in theoretical sciences which involve scribbling, doodling, playing around with concepts, symbols and so on.[17] While indulging in this playful activity, that is, 'doing' with no particular purpose and without taking anything seriously, scientists stumble upon some important insights. This aspect of creative thinking is an integral aspect of science. This implies that while doubt, in the various ways discussed above, is an important category for science, the capacity to 'hit' truth and knowledge without in any sense starting from doubt questions some of the basic presuppositions about the foundational nature of doubt.

A sociology of knowledge will show how scientific discourse

and scientific knowledge are created not only through the methodological priority given to curiosity, doubt, rationality and so on but also through factors such as play, success and competition. The idea of competing, of being the first, of doing better than the other, is one that is ingrained in the scientific community. Creating knowledge then becomes a social act, with its own set of rituals. Knowledge is then much less concerned with doubt as it is with various other constraints, including finding resources, getting awards, needing to publish and so on. Many times, ritual acts themselves are part of the knowledge-creating activity. The importance of Descartes' universal and hyperbolic doubt perhaps lies in the possibility that they make doubting a ritual. What dictates a large part of scientific research activity today does not necessarily arise from doubt per se but from various pragmatic concerns, including the possibility of action based upon some ideology, ritualistic practice (both theoretical and experimental) and so on, all which cumulatively leads to scientific knowledge. Understanding this aspect is to enter the world of rhetoric, debate and dialectic.

2.6 *Resolving Doubt and the Process of Knowledge*

For Nyāya, the resolution of doubt is a seven-step process that constitutes the 'preliminaries' of philosophical debate.[18] Indian philosophy manifests a dynamic culture of debate, both between members of a tradition as also with those in other traditions, including their opponents. Both in the Indian and Greek traditions, the process of thinking and arguing have been deeply influenced by their emphasis on debate and dialectic. Even the 'methodology' of moving from doubt to certainty has, as Matilal notes, its origins in the 'very ancient Indian discussion of the art of disputation and philosophic debate.'[19] The emphasis on debate as a form of public discourse in both ancient Indian and Greek traditions indicates the importance of knowledge as a public category.

The structure and kinds of debate also exhibit the practice of rational discourse where one can hold different positions and discuss and argue about them. The idea of debate and argument has survived over the centuries and today's academic discourse is filled with elements of the early theories of debate.

The Greek views on debate and dialectic are well known. The Indian contributions to these areas are similar on some counts and dissimilar in some ways. The most relevant point to note is that debates in various Indian traditions were the means to dispute various philosophical theses and theories, thereby reflecting a strong rational tradition within Indian philosophy. Every form of debate included a central component of reasoning. Evidence for their positions had to be upheld in a most rigorous way and this in turn gave rise to various kinds of defeater-situations, classifications of the types of mistakes in argument and evidence, and so on. While science studies has drawn upon rhetoric, drawn from the Greek tradition, to understand the role of rhetoric in science, a corresponding analysis of rhetoric and debate from Indian traditions is sadly lacking. At this point, it may be premature to say that rewriting the rhetoric of science from an Indian perspective will yield new insights into this aspect of science. However, it is equally possible that we may find that debate as practiced in Indian philosophical traditions, spread over not only centuries but also between proponents of the same school as well as with opposing ones, actually offers a complex analysis of the relationship between dialectic, argumentation, debate and rhetoric with science. To motivate this larger project, I will briefly discuss the salient points of the art of Indian debate and disputation.

The earliest contribution to the formal structure of debate came from the Buddhists. Largely, the structure of this form of debate consisted of the statement of a thesis which was refuted by the opponent, basically using logical rules. Most of their arguments can thus be expressed in the form of implications.[20] Caraka's classification of debates into two

types, namely, amicable and hostile debate, and the further sub-classification of these types, was influential in the sense that many of the terms picked up by later philosophers originate from him. Instead of going into the details, I will only list some essential points here. Nyāya, which offered a more systematic account of debates, described three kinds of debate. First is the 'honest' debate (*vāda*), second is the 'tricky' debate (*jalpa*) and the third is the 'destructive' debate (*vitaṇḍā*).

The first kind of debate is an intellectual one, where the use of reason and the art of persuasion are used to support one's position. Reason is defined in terms of the five-step process that describes how a conclusion is arrived at (more on this in the next chapter), the relation between the evidence that is available and the thesis that is propounded, use of logical arguments including *tarka* and the availability of not only a properly formulated thesis but also a counter-thesis which can be identified and refuted.[21] Matilal notes that the insistence on proper formulation of the counter-thesis was important since it led to the conceptualisation of the rule of contradiction, which allows us to identify when a thesis is contradictory to another. This kind of debate, conducted only with an aim to learn and be logically rigorous in argumentation, occurred between proponent and teacher, for example.

The second kind, *jalpa*, had victory as its goal and not truth as in the first one. Since victory was the real goal of this debate, the debaters could use, other than reason and arguments as in the first type of debate, various tricks to defeat the opponent. Three means, quibbling, illegitimate rejoinders and clinchers are allowed in this kind of debate. Each of these three means is classified into many different kinds. This classification allows a debate to proceed smoothly since to refute a particular move one needs only to note what kind of a mistake it is, which immediately explains the problem in the argument.

The third kind is called *vitaṇḍā* and is characterised by

the fact that there is no counter-thesis which needs to be established. Recollect that the first debate had to have a counter-thesis if one was arguing against a particular thesis. This actually puts the burden on the opponent to frame the argument in positive terms, that is, the debate is not only to show why some thesis is wrong but also to show what could replace it. The third debate, which has been seen as irrational and unfair kind of argument, is concerned only with demolishing a particular thesis without constructing alternatives. So this was also seen as a 'destructive' debate.

The careful classification of the kinds of tricks that can defeat an opponent attests to the role of logic and analysis in matters of debate in Indian philosophy. The three types of tricks that are allowed in the second form of debate, *jalpa*, are further classified into many sub-types. Three kinds of quibbling, twenty-four of illegitimate rejoinders and twenty-two of clinchers are listed and discussed with examples. Although it will be a useful exercise to go through these examples, I will not do so here and restrict myself to one particular observation.[22] We can identify two kinds of problems that arise in the description of these tricks and mistakes in argument. One set of problems is psychological, in that it shows what psychological factors can cause mistakes in an argument. This includes mistakes such as 'incomprehensible speech', 'silence', 'lack of intellect' and so on, arising in the midst of a debate. There are also epistemic conditions such as incoherence and using pseudo-reason. The importance of the Indian theories of debate resonates through various philosophical problems down the ages, thereby profoundly influencing the growth of logic and the larger rational discourse.

The emphasis on debate, the careful unpacking of the various kinds of arguments and reasoning that is allowed in a debate, the methods of defeating an argument and so on, illustrate the difficulty in establishing a public, rational discourse. The difficulty arises for a simple reason. It is easy for an individual to claim access to some knowledge

and truth. But the very nature of these terms demands a public acceptance or at least acceptance by a community. How do we make this transition of a particular belief, thesis or claim from the individual to a collective? How do I convince somebody else about my insights? What is the movement from the subjective to the objective or at least to inter-subjectivity? Although not phrased exactly in these terms, theories of debate and dialectic consistently engage with these questions. The intricate classification of the various themes that occur in a debate indicate how it is reasonable to make a transition from a personal viewpoint to a collective one.

One of the essential problems for science is this shift from individual enlightenment to its collective acceptance. The process of debate and the constraints placed upon it only increase the probability of knowing that a subjective awareness can be an objective fact. For science, this problem is manifested at the most fundamental level. It is scientists who create science and its set of truth statements. But once it is so created, there is no authority of the scientist over it. It becomes part of the truths held by a community. How do we then choose from a large set of subjective insights and accept them as objective knowledge and truth?

In science, there are two major modes of validating, illustrating and convincing others that a particular thesis is indeed correct. One is the experimental and the other the theoretical mode. Experiments confirm various scientific statements. But it is not easy to know which statement an experiment confirms or to argue convincingly about the link from a particular evidence to a particular thesis. Unfortunately, a piece of evidence does not come with a label attached to it saying that it shows something else to be true. In the following chapters, I will discuss the theory–experiment relation in greater detail. Even theoretical, mathematical proof, is dependent on various rhetoric strategies. Mistakes in arguments are always possible. Some of them have to do with the kind of assumptions that are

made, choice of certain kinds of mathematical terms, using them in incorrect ways and so on. Thus, for any scientific claim to be possible, there has to be persuasive, rhetoric strategies to help establish that claim, however strong the 'evidence' may be. Since truths are not self-revelatory, they have to be established through arguments and in doing so there may be mistakes. Indian philosophers attempted to give a classification of the kinds of mistakes that are possible. In the next chapter, in the section on pseudo-reason, we will see more detailed analysis of the kinds of wrong reasons one can make according to these philosophers. What they are doing, either in their analysis of doubt, debate, logic or truth, is to place stringent demands on reason. They extend their suspicion of perception, which arises due to our experience with illusion, perspective and so on, to reason. It is the illusion of reason that demands a critical perspective and knowing the mistakes we can make in reasoning is one way to limit the boundaries of reason.

Obviously, it would be a little far fetched to claim at this point in the book that Indian philosophy would generate a new philosophy of science. I am nowhere near making this claim nor interested in doing it. What seems to be clear, however, is that many themes in Indian philosophy, particularly the rational elements of its many traditions, share a great deal with similar themes in science. Sometimes, when people ask what can philosophies propounded centuries ago have in common with modern science, they miss the basic point that at its foundations science is still saddled with fundamental philosophical issues. The practice of science brackets these and proceeds with little thought to them. In the following chapters we will continue to explore how the foundations of modern science can be illuminated with the help of various philosophical traditions, old and new, West and East.

3

INDIAN LOGIC

Historically, modern science in the West has always claimed a special relationship with logical reasoning and rationality, which were then used to differentiate it from various other human activities. Moreover, the creation of disciplines such as those that fall under social sciences was strongly influenced by the special status accorded to this logical activity called science. Concurrently, technological progress, even though not in a simple and linear relation with science, was a further reaffirmation of the logical, objective and rational character of science. Not much has changed even now in the popular imagination in spite of various historical, philosophical and sociological insights into the nature of science.

A consequence of this image of science was that other cultures were denied any claim to science or, in many cases, even as possessing the capacity for scientific thinking, a mode of thinking which was thought to be purely logical and rational. It is not an accident that the apparent lack of scientific thinking in other cultures parallels the apparent absence of the discipline of logic in these cultures. Science and logic, in this particular case, are indeed brothers-in-arms, coming together to deny a particular way of thinking and worldview to other civilisations. However, there are two problems with these claims: one is the relation between science and logic, a relation that has been primarily explicated through the use of Western philosophical categories and the other is the belief in the absence of a

logical tradition in other cultures. In what follows, I will address both these issues.

What exactly is logic and how is it related so exclusively to the West? Logic is simply a method of argumentation and analysis of such arguments. In its simplest form, it is an activity which allows us to go from some given premises to a conclusion. An introductory text in Western logic begins by noting that logic is 'about reasoning—about going from premises to a conclusion' and defines it as 'the analysis and appraisal of arguments.'[1] In so doing, it uses a variety of logical ideas and terms such as conjunction, negation, contraposition and so on. What we usually call as logic is a particular process of reasoning which has some structure and validity, a process which is manifested not only in a variety of disciplines but also in our ordinary activities.

In the Western tradition, the standard examples of logic begin with Aristotelian syllogisms. These are structures of reasoning which have two premises and a conclusion which follows from these premises. A common example is as follows. The two premises are: 'All Greeks are mortals' and 'Socrates is a Greek'. The conclusion is: 'Therefore, Socrates is a mortal'. This conclusion is reached through a process of deductive reasoning, a form of reasoning which is independent of the terms in the premises. All that is required of deductive reasoning is that two true premises should not yield a false conclusion. Aristotelian syllogisms are characterised by three terms: major, minor and the middle term. The middle term is what is common between the premises, the minor term is the subject and the major term is the predicate in the conclusion. So in the above example, the middle term is 'Greek', minor is 'Socrates' and the major term is 'mortal'. We can also write this syllogism as an example of the following: 'All A is B, x is A, Therefore, x is B', where A is the class of all Greeks and B is the class of mortals. The substitutability and the extensionality of these terms are important characteristics of this form of argument. Another important factor is the indifference to the existential status

of entities in the premises. This means that this syllogism will be valid even if we replace Greeks with conceivably anything else, say Martians. This character is described by saying that the deductive structure is concerned only with the validity of the structure of the argument and not about its soundness, namely, whether its premises are true or not. Logic, in this sense, is indifferent to whether terms in the premises are even real or not. Logic is primarily concerned with inference, the standard types being deductive and inductive inference. Another typical example is the *modes ponens*, which consists of the following deductive structure: given a conditional statement of the form 'If p, then q', then given 'p', we infer 'q'. Various interesting consequences of the conditional statement can be formed, including its contrapositive which would be of the form 'If not-q, then not-p'. The standard dichotomy in Western logic is between deduction and induction. Deductive inferences are not dependent on experience or empirical content in that the conclusion that is drawn is independent of whether the premises are true or not. Inductive statements typically generalise and extrapolate. Consider a common example of induction: seeing smoke, we infer that there is fire, because of our past experience and knowledge about the relation between smoke and fire.

The development of modern logic included topics such as predicate logic, propositional logic, modal logic and so on. The use of symbolic methods was an important qualitative shift in the development of logic. The relation between mathematics and logic was also extensively studied. Modern logic consists of all these sub-disciplines and is primarily symbolic in character. When we talk of Indian logic, we need to note the absence of symbolic form in the original formulations. Although there have been interesting attempts to symbolise Indian logic, it is not clear what the symbolisation does to the essential character of this logic. In the following section, I will summarise some of the important logical traditions in India and conclude with a

summary of the relevant themes that are essential to these logical traditions.

3.1 *Logic in India*

All dominant philosophical traditions in India engaged with logic and the magnitude of this engagement depended upon particular traditions. Nyāya and Buddhism made seminal contributions to logic while other traditions marginally dealt with various disputes about certain themes connected with logic. Jainas developed a logical formulation that was distinct from the standard accounts of logic in ancient and medieval India.

Matilal describes Indian logic as the 'systematic study of informal inference-patterns, the rules of debate, the identification of sound inference vis-à-vis sophistical argument, and similar topics.'[2] The standard practice when dealing with Indian logic is to begin with the nature of debate, a topic which I have briefly introduced in the last chapter. In what follows, I shall discuss in some detail the various kinds of inferences (*anumāna*) that were discussed in the Indian systems and also some of the philosophical themes associated with inference. Where relevant, I shall make appropriate connections with philosophy of science.

There are many issues related to inference. First of all, how do we infer? What do we infer? Why do we infer what we infer? Inference, in general, can be understood as the capacity to say something more than what is known initially. This capacity is already one that is central to the definition of reason. Reason allows us to know more than is available to us through the senses and inference is one important way by which we transcend the limitation of sensory experience. This capacity to know more than what is available to us through experience seems to be universal and is exhibited in our day-to-day lives as well as in specialist activities such as science.

Indian philosophical systems have a theory of knowledge which claims validity to different means of knowledge.

Perception is common to all of them as is inference, with the exception of one school, the materialist Cārvākas. Thus, in Indian philosophy, it would be safe to say that in general inference was accepted as a valid instrument of knowledge. However, we know that many inferences we make turn out to be wrong and thus any general claim about the validity of inferential reasoning should respond to this issue. Also, in response to the spectre of wrong inferences, an important task for Indian logicians was to critically understand which inferences are valid and what conditions they should obey in order to have certainty. Indian logicians were deeply concerned about establishing an elaborate theory to know which inferential statements one could be certain about and the methodology to decide on their validity. It may be useful to remember here that Indian logic shows distinctive characteristics, some of which are very different from the Western logical traditions. This is because, as Matilal notes, logic in India arose out of two different traditions—one, the tradition of debate and dialectics, and the other, the epistemological, empirical tradition, because of which the distinction between logic and epistemology, as in Western logic, is not made in Indian schools of logic.[3] In what follows, I will discuss some of the important ideas and traditions in Indian logic and philosophical themes that arise in them. Not all themes present in these philosophical systems are discussed and I have chosen to focus on those which, I believe, have a potential relevance for philosophy of science.

3.2 *Nyāya*

The earliest structure of inference in Indian systems, 'similar' to Aristotelian syllogisms, consisted of ten steps and sometimes more. However, the five-step structure associated with early Nyāya is the standard illustration of Indian inference. Nyāya is the primary Indian logical tradition. Its earliest extant text comprising even earlier aphorisms is the

Nyāyasūtra and is usually dated around the second century AD. Nyāya's logical theories arose from a long tradition that debated the nature of inference both within the tradition and as a response first to the Buddhists and later to the Vedāntists. A school of logic arising from Nyāya and called Navya-Nyāya (new Nyāya), further clarified and developed important concepts in logic from thirteenth century onwards. It is instructive to look at these earlier views in order to understand the range of inferential statements. Ancient Indian schools had slightly different accounts of inference. The Vaiśeṣika and Mīmāmsā schools had a two-fold classification whereas Nyāya, some Buddhist schools and Caraka had a three-fold classification. This latter classification influences the kinds of examples which the later logicians were concerned about and also gives an inkling into the larger issues they were concerned with. I will briefly describe them here mainly in order to exhibit the similarity of concerns that arise in any analysis of inference.

The first kind classifies inferences in which the effect is inferred from perceiving the cause.[4] The idea of cause in this case is captured in the phrase 'as before'. This kind of inference, called *pūrvavat,* classifies inferences based on a prior nature. The ability to infer that an adult I see now is the same as the child I once saw based on the fact that both of them have six fingers is an inference based on the nature of 'as before'. It is easy to see that the essence of 'as before' is also captured in some causal statements. The possibility of recognising some characteristic which is 'as before' entails constancy of something—sameness of a mark, event and so on. It is only a recognition of the 'as before' character which is also exemplified in certain kinds of inferences based on recognition of causal links. Another example of this kind is to infer that it will rain because there is a cloud. Because one sees a cloud, one infers that it will rain because this is known from earlier instances. Here, the inference is of the effect from perception of a (presumed) cause.

The second kind of inference is *śeṣavat* —'rest will be

alike'. Matilal notes four different subtypes of inference that have been placed within *śeṣavat.* One example is the inference that all drops of seawater are salty from tasting just one drop of it. Here, the meaning of the phrase 'rest will be alike' is self-explanatory. This example is an extrapolation from experience of earlier instances and is a common example of induction. Another example of this type is the inference that all grains of rice are cooked from knowing that one grain of rice in a pot is cooked. Here the movement is from one instance to all possible instances. The second subtype is the inference of cause from effect, the opposite of *pūrvavat.* The standard example is the inference that it has rained because the river is full and flowing swiftly. The third subtype is 'remainder', namely, inference by 'elimination of alternatives'. This explains inference which we reach by eliminating other possible alternatives rather than infer 'directly'. And finally, the fourth subtype, gives the example of inferring the whole from the part; the example being the inference of a whole cow from seeing only its parts.

What kind of ideas are these types of inference based upon? Is there a qualitative difference between the mechanisms of inferring from the cause to the effect and vice versa? Or is the process of inference the same? If the latter, then what is accomplished by this classification of kinds of inference? There is an obvious asymmetry in the direction of movement from cause to effect. Given cause, inferring effect can be different from given effect, inferring the cause. One can try and analyse this difference in terms of temporality. Since cause is temporally prior to the effect, the direction of inference may seem to mimic the distinction between this direction of time. There is some debate on the exact role temporality plays in these classifications but I shall not deal with it here.[5]

The third kind of inference is called *sāmānyatodṛṣṭa.* It has been argued by some that this kind of inference is the same as *śeṣavat.* Inference in the absence of causal connection comes under this category. Examples given are: inference

that there is water nearby because wild geese are present; inferring the taste of fruit from seeing its colour; inferring specific taste from specific smell.[6] In all these examples, there is no cause–effect relationship. Colour is not a cause for a particular taste of a fruit although appropriate changes in the growth of the fruit may cause a particular colour and a corresponding taste to occur at the same instance. Another example is the inference that celestial bodies move because we know that ordinary bodies are displaced due to motion. Since celestial bodies are also displaced, we can infer that they must be moving. Another set of examples of ancient logic is from Caraka.[7] His three types of inference are similar to the ones discussed above, although these are expressed in terms of temporality. The first is the inference of past from present or cause from effect; the example is inferring sexual intercourse from pregnancy. The second is the inference of future from present, or effect from cause, the example is inferring future fruition from the seed. The third is the inference of the present from present, as illustrated in inferring fire from smoke. These examples of inference are given only to illustrate the detailed nature of the analysis of different kinds of inference, even in times before logic was well understood as such. Note that inference of future cases from present ones, or inferring effect from cause is an important part of prediction. Therefore, for these cases, analysis of what constitutes good inference will actually be an analysis of what constitutes valid modes of prediction. In the above examples, we can see the importance of themes such as prediction, explanation and inference. The relation between these themes will be explored in greater detail in the following chapters.

Perhaps the most common example of inference in Indian logic is that of inferring the presence of fire from seeing smoke. The analysis of this example illustrates a deep and complex engagement with the idea of inference and various related philosophical themes. Some of the questions concerning this example are the following. How do we infer

that there is fire given that we only see the smoke? How can we establish the validity of this conclusion? What are the criteria for knowing that our inference is right, that we are justified in making it? What kind of inferences can give us certainty? There are two kinds of inferences described by the Naiyāyikas and the Buddhist logicians. One is the inference one makes for oneself. This occurs when one sees smoke on a hill and then infers to oneself that there is fire on the hill. There is no further communication or need to convince somebody else about this inference. The other type of inference is called inference-for-others, which is an explanation of the inferential process to convince another person of the correctness of the inference. Nyāya has a five-step process to accomplish this. The five parts are (1) the statement of the thesis of inference (2) stating the reason or evidence for this thesis (3) citing an example of a generalisation supporting the reason and this example is such that it is well accepted by others (4) application of the present observation to the generalisation and (5) conclusion or assertion that the statement of the thesis has been proven. The well-known illustration of these five steps is as follows.[8]

1. Proposition: There is fire on the hill.
2. Reason: For there is smoke
3. Example: (Wherever there is smoke, there is fire), as in the kitchen
4. Application: This is such a case (smoke on the hill)
5. Conclusion: Therefore it is so, i.e., there is fire on the hill.

The structure of argument sets out a rational, logical way of convincing others that the inference one makes is perfectly valid. The first step states what is to be inferred. The second step states the reason, which is smoke, for making the inference. The reason in conjunction with a more general principle or 'natural law' that we know allows us to make the inference. But given Nyāya's commitment to empiricism, any inference we make has to be grounded in some

observations, as given by examples. These examples should be commonly accepted and can be both positive and negative examples. Positive examples are those which support the inference, such as a kitchen because in the kitchen we know that smoke and fire are seen to occur together. Negative examples, such as a lake, support the inference by looking at places where there is no fire. The fourth step applies this general principle to the case at hand and finally, the fifth step, states the conclusion as being established.

This five-step process is an exemplar of Indian logic and is the Indian logic's 'equivalent' of Aristotelian syllogisms. In the way it is presented, it seems clear that this process is not what was understood as logic in the West, largely because of the use of examples and inference of a singular case. I will discuss this issue in greater detail later in this chapter.

The *nyāya* model of inference was modified and replaced by an influential formalism by Dignāga, the Buddhist logician. In so doing, new themes were emphasised and these themes introduced new direction to the study of inferences. In what follows, I will discuss some basic ideas of Buddhist logic and then at the end of the chapter summarise various philosophical themes arising from all these traditions, including that of Navya-Nyāya, the new logic which was established in the post-Buddhist period.

3.3 *Dignāga and Buddhist Logic: Sign and Inference*

The idea of a sign is central to human thought. A sign is in general understood to be a mark of, as standing for, something else. For example, the word 'cow' is a sign that stands for the object cow. A photo of a cow or a cartoon of it are also signs that indicate a cow. The capacity to relate two entities in the manner of relation of sign to the signified (that which is being referred to by the sign) is already a prime indicator of abstraction, a step which naturally leads to generalisation. Therefore, it should not surprise us that the

concept of a sign plays an important role in Indian logic as well as in modern science. However, the concerns about the nature of sign in Indian logic are circumscribed by some particular restrictions relating the sign and its signified. Given a sign which stands for something else, what can we say about their relation? In the history of Western thought, the study of signs became a separate discipline called semiotics. In the Indian context, the notion of sign became central to logic and the analysis of the nature of sign predates some of the later Western conceptions of it.

A complete elaboration of the meaning of a sign, its relation to what it signifies, and the relationship between sign and inference had to wait for the great Buddhist logician, Dignāga (c. 450 AD). He turned the question of logic into a question of semiotics. Inference by its very nature is related to signs. Inference occurs when we come to believe in something which we do not directly perceive. Inference allows us to expand our perceptual capabilities, at least the 'perceptual' capabilities of the mind with the help of inferential, logical reason. It also seems to be the case that we do not make arbitrary inferences. For example, although I have always seen the podium in the lecture hall and seen the same in other lecture halls, I do not believe that the podium and the lecture hall are related like smoke and fire. Also, we do not infer goats from seeing smoke. We accept that the presence of smoke is indicative of the presence of something else on the hill and in this case it is fire. Therefore, smoke, first and foremost, has to be considered as a sign which is in some sense related to what we infer. Dignāga's logic is primarily an attempt to clarify what kinds of valid signs are possible and how we can make justified inferences from these signs. We can see an important difference between the *nyāya* five-step process and Dignāga's formulation. In the *nyāya* process, the generalisation 'wherever there is smoke, there is fire' is one step in the five-step process. It is used as a part of the reasoning, whereas for Dignāga, it is precisely the reason which he wants to 'prove'. In this sense, Dignāga is concerned

with justification of an inductive statement such as, 'Wherever there is smoke, there is fire'. He wants to know how an inductive cognition can be made certain.

There is yet another peculiarity in his formulation and this has to do with the synonymic usage of sign, reason and evidence. Smoke is the sign which indicates the presence of fire. Smoke is the evidence for believing that there is fire and the presence of smoke is also the reason for coming to the conclusion that there is fire. Thus, as Matilal notes, sign, reason and evidence are terms that are often used interchangeably in Indian logic. Dignāga's theory of inference describes a structure of inference based on the nature of the sign, thereby defining when a sign can properly stand for another. He formulated the 'triple nature of the sign', three conditions which a sign must fulfil in order that it leads to valid inference.

1. It should be present in the case (object) under consideration.
2. It should be present in a *similar* case or a homologue.
3. It should not be present in any *dissimilar* case, any heterologue.[9]

The sign, as pointed above, is also the reason for the inference and is called the *hetu*. The inferred property is *sādhya* and location is *pakṣa*. In our example, smoke is the sign for fire. To know if smoke is really a valid sign pointing to the presence of fire, we need to check whether it satisfies all the three conditions. Dignāga's first condition says that such a sign (smoke) should be present in the particular case under consideration and this is satisfied since smoke is seen on the hill. The hill is the subject-locus, the *pakṣa*. Seeing the smoke arising from the hill, we infer the existence of another property, fire. The second condition is that there should be examples of other similar locations which possess the sign (smoke). The example of the kitchen is one such, since the kitchen is also a place where we see smoke and fire together. We can understand this second condition as giving a positive

example supporting or confirming the inference we make.

The third condition is a negative condition. It says that the sign, if it is to be a valid sign, must not be present in locations where the signified is not present. That is, smoke should not be present where fire is not present. If smoke were so present, then it would imply that there is no necessary connection between smoke and fire. In a sense, which will get clarified as we go along, Dignāga and later logicians are trying to articulate what it means to have this 'necessary' connection although they do not phrase it in terms of necessity or, in general, in modal language. The example for the third condition is a lake which is not a locus of fire. So, if smoke is found over a lake where fire cannot, by necessity, be found, then it surely rules out the necessary relation between fire and smoke.

To summarise the meaning of the above conditions: a sign which is present in a locus signifies another property of the locus. To have a degree of certainty about this signification, we need to find similar cases where the sign and the signified occur and also dissimilar cases as explained above. The occurrence of the sign and signified together is seen as illustrating a relation between them, the relation of invariable concomitance or pervasion.

The second condition demands that there should be at least one similar case. Obviously, there can be more than one similar case. For example, kitchen is one similar case in that smoke is present there along with fire. There could be other similar locations such as a forest. All these similar cases constitute the similar or homologue class. What is the role of this condition? To answer this, we first have to be clear about what is really being inferred. In Dignāga's formulation, it is the connection we make between one property and another that needs to be analysed. The inference we make is that smoke is always to be found with fire. Obviously this statement cannot be verified completely because there may be places where we cannot empirically check whether this is the case. Also, we cannot know whether

this relation will hold in the future. So, statements of this kind, such as 'wherever there is smoke, there is fire' or 'all crows are black' cannot be verified in principle. However, we can increase our confidence in these claims and this confidence increases when we find more cases that illustrate this statement. The second condition is just verification of the statement.

For the Indian logicians it seems that verification or confirmation is not enough to establish the truth of the relation. There is thus an implication that however many confirmed cases there are, we will still be unsure about a particular relation. The important implication of the third condition is that the second condition alone is not sufficient to guarantee the relation in an inference. Thus, it is a statement of the limitations of verification or confirmation and suggests that just because there are many verified cases, it should not be taken to mean that it is enough to establish the truth of an empirical generalisation.

Verification or confirmation of a hypothesis is not sufficient to establish it. We can say that it is impossible to confirm such generalisations or we can look for other means to improve our confidence or find rational reasons to accept the truth of these generalisations. Dignāga's third condition is an attempt to look for another condition that will help establish the generalisation with certainty. The dissimilar cases are cases which do not positively verify or confirm the relation. These are negative examples in that we look for cases where there is no smoke and use that as evidence to make an inference about the smoke–fire relation. The importance of the third condition is based on the simple observation that one counter example is enough to demolish an argument. One example of a white crow is enough to show that the statement that all crows are black is wrong whereas even thousands of black crows cannot conclusively prove that all crows are black. Negative instances are powerful indicators of a positive relation. This is especially true in judging the validity of inductive inferences. The third condition

thus demands that there should not be cases where smoke is present when fire is absent. Because if this is so, then obviously there are cases where smoke is present even when there is no fire thereby leading to the conclusion that fire is not necessary for smoke. So, the third condition implies that disconfirmation is a necessary condition for establishing the invariable concomitance relation. To find dissimilar cases, we look for those places where the inferred property is absent. We go to a lake to find a dissimilar case because a lake is a location where there can be no fire. The set of all dissimilar cases constitute the dissimilar class.

Thus, the three conditions imply that confirmation or disconfirmation alone are not enough but that they have to be factored together. It is worthwhile to read this along with Popper's terminology. For Popper, confirmation of a hypothesis does not amount to much, at least not as much as attempts to falsify that hypothesis. In other words, if a hypothesis is open to being shown wrong, then it is a better scientific hypothesis. When Indian logicians claim that the second condition alone is not enough and insist on the third condition, they are in essence claiming that the truth of the inferential hypothesis needs to show evidence that it cannot be proved wrong, as well as showing that it can be proved right. However, there are also some important differences between this formulation and Popper's, some of which I will discuss in the next chapter.

There has been much discussion on whether the second and third conditions are really independent of each other. One influential argument has been that the third condition is nothing but the contrapositive of the second. Suppose we have a statement of the form 'If p, then q'. This is an implication, the form of many of our common inferences. This statement is logically equivalent to 'If not-q, then not-p'. Logical equivalence means that whatever evidence makes the first statement true is also the evidence which makes the second one true. Dignāga's third condition seems to be nothing but the contrapositive of the second, in which case

both these conditions are logically equivalent. (The contrapositive of 'If smoke, then fire' is 'If not-fire, then not-smoke', which is essentially the third condition.) But to grant this point would be to miss something important in the three conditions. First of all, it is not clear whether the language of contrapositive and the equivalence of an implication and its contrapositive follow from the unique characteristics of Indian logic. Further, as Hayes has argued, we can understand the non-equivalence of these two conditions based on the specific characteristics of association and dissociation relations which Dignāga uses.[10]

The problem is that conditions one and three seem to be sufficient for making a sound inference. Why then the insistence on condition two? One way of understanding the second condition is that it gives a set of positive examples that will support the inference. Once we have a negative example then what use are positive examples? As mentioned above, one negative instance is enough to show an inference to be wrong whereas countless positive instances can still not guarantee that the inference is right. Once one has evidence from negative examples is that not enough? The problem is that in Dignāga's case the negative example is used to make a positive inference and not just to negate an inference. That is, the negative case of smoke not being present over a lake is also a support for the inference of fire in the hill. In the case of confirmation, the existence of a negative example (such as one sighting of a white crow is enough to show the invalidity of the inference 'all crows are black') negates the inference. This is crucial because what the third condition is asking for is not that the inference be shown to be wrong but that it can be shown to be right through a negative case.

Matilal discusses this issue in detail and he makes two important points. One has to do with epistemologising logic, a characteristic of Indian logic that will be discussed in more detail later in the chapter. Associated with this is the suggestion that the meaning of negation, contraposition,

contraries etc., is quite different in Indian logic. Matilal suggests that A not being together with non-B (the negative case) does not necessarily imply that A and B are together because there may be the possibility that 'an A is neither B nor non-B' in which case the contrary example alone is not enough. Therefore, '"not non-B" is not always equivalent to "B".'[11] The second point is the problem of contraposition itself. It is related to the above problem of existential status of the terms used in inference. Further, the problem in correctly designating the contraries (of the inferred property) necessitates positive examples so as to reach complete certainty of the inference.

It might be mistakenly thought that signs are restricted to material signs such as smoke. This is not true since sign and reason are used interchangeably. Thus, Dignāga's conditions are as much conditions which a reason should satisfy if it should be seen as being correctly associated with some thesis. Similarly for evidence. Suppose we say that we have evidence for some inference we make. Then to know if this is a valid evidence or not, we should check if the three conditions are satisfied. As we can easily see, this kind of check can be performed on any inference we make, including scientific inferences. Rewriting the three conditions in the following manner makes us see this character of the three conditions more clearly. Bharadwaja interprets the conditions in terms of the thesis and the reason which is adduced for the thesis.

(1) The *hetu* advanced in justification of a thesis must be relevant to the thesis.
(2) It must support the thesis.
(3) It must not support the opposite of the thesis.[12]

The thesis is the inferential statement. The reason is that which supports it. For example, consider the thesis: 'Sound is impermanent, because it is audible'. The inferred thesis is the impermanency of sound and the reason for holding this thesis is the audibility of sound. If this reason is logically

valid to explain the thesis, then it should satisfy the three conditions. Bharadwaja, in focussing the issue in this manner, believes that it is a more useful way to understand it in contrast to attempts by Potter and others to rewrite these conditions in the language of deductive logic and class relations. The problem in writing these conditions in this manner is that it is not clear what 'relevance' and 'support' actually mean, whereas the invocation of the language of similar and dissimilar cases makes this meaning explicit.

3.4 *Classification of Reason: Wheel of Reason*

Given these three conditions which a valid sign must obey, it is possible in principle to form various combinations of them, such as signs which have some similar cases but no dissimilar cases. Dignāga describes nine such kinds of possible combination in the 'wheel of reason' in *Hetucakranirṇaya.* These kinds of reason are exemplified through various examples. Dignāga's examples deal with the nature of sound, whether it is eternal, non-eternal, produced or not-produced.

The first example discussed by Dignāga is this: 'Sound is eternal, because it is knowable like the space and the pitcher.'[13] The reason, *hetu,* is 'it is knowable' and we want to know whether this is a valid reason to claim that 'sound is eternal'. If it is indeed a valid reason then it should satisfy the other conditions. In this case, we find that the reason is too general and supports the counter-thesis that sound is non-eternal as well as the thesis that sound is eternal. Because of this fallacy of reason, this particular reason 'it is knowable' is not a valid reason for the thesis 'sound is eternal'. This example illustrates how we can analyse whether a given reason for a thesis is valid or not. The remaining eight theses and reasons are as follows.

1. Sound is non-eternal because it is produced like the pitcher and the space. Reason here is 'it is produced'. Similar case is pitcher and dissimilar case is space.

2. Sound is produced by effort because it is non-eternal like the pitcher, the lightning and the space.
3. Sound is eternal because it is produced like the space and the pitcher.
4. Sound is non-eternal because it is audible like the space and the pitcher.
5. Sound is eternal because it is produced by effort like the space, the pitcher and the lightning.
6. Sound is not produced by effort because it is non-eternal like the lightning, the space and the pitcher.
7. Sound is non-eternal because it is produced by effort like the pitcher, the lightning and the space.
8. Sound is eternal because it is incorporeal; or, because it is tangible like the space, atom and action.

Given these nine types of reason, only two of them satisfy all the conditions for valid reason. These are reasons 2 and 8. For the thesis that sound is non-eternal the two valid reasons are that it is produced (by effort). We can also understand this in the language of locus (*pakṣa*) described earlier. The locus in this example is sound and the property of non-eternality is to be inferred based on another property of sound, that it is produced. There are both similar and dissimilar cases for these two valid reasons. Similar cases would be those where the locus is different but the two properties are to be found in one locus. In this example, the similar case is the pitcher. The pitcher is the locus and it is an example of a similar case because we know that a pitcher is produced and it is also non-eternal. Any similar locus which is produced will be non-eternal (which is a given truth to the Buddhists).

For the dissimilar case we need a locus which cannot be non-eternal (just like lake cannot have the inferred property, fire). Space, for the Buddhists, is not non-eternal. Now, if space were to be produced like a pitcher or perhaps sound, then an eternal thing could also be produced thereby implying that being produced is not sufficient reason to claim that something is non-eternal. Since space is eternal and not

produced this reason has a dissimilar case, thereby satisfying condition three. Therefore, this reason is a valid reason. Analysis of the other cases is on similar lines.

Hayes argues that Dignāga was formulating his philosophy along the lines of the sceptics and as such his 'main interest was not to find a way to increase our knowledge but rather to find a way to subtract from our opinions.'[14] The statements that are being analysed are on the order of hypotheses and therefore they are open to confirmation and disconfirmation. Hayes believes that Dignāga's theory aims to compare different classes. Hayes' use of the word class might clarify the distinction between this approach and that advocated by Bharadwaja. Classes are a collection of individuals. We can construct classes as extensions, that is, as the set of individuals which share a common property. An example would be the class of all red things such as red house, red shirt and so on, which would be an extensional class corresponding to the property red. Or, we can describe properties in themselves rather than through objects which have those properties. Describing properties in themselves is called the intensional description. For example, we could describe the red colour in terms of its wavelength and not through pointing to red objects. Hayes notes that although Dignāga (and Indian logicians in general) used only intensional descriptions, one can show an appropriate equivalence with the extensional mode; that is, we can either talk about properties or classes which exemplify this property and therefore there is some justification in using the language of classes to talk about Dignāga's logic.

Dignāga's views on inference are sketchy in the *Hetucakranirṇaya* but his work *Pramāṇasammuccaya* is a more detailed and complete treatment of inference, which includes the analysis of the three conditions for valid inference. Hayes clarifies the difference between these two important texts in the following manner. In the former, Dignāga discusses inference as part of debate, which was already present in the tradition before him. The three conditions were expected to

be obeyed by any piece of evidence in a debate. In the case of debate one is trying to convince others of the inference one makes. Hayes argues that in his later work Dignāga uses these three conditions to determine for oneself (and not for others) the validity of some inference. This observation might also help us understand what seem to be significant differences between the *hetucakra* and the three conditions for valid inference. The distinction between inference for oneself and for others is part of the larger Indian philosophical discourse, which explicitly makes such a distinction. Both Nyāya and Buddhist logicians formulate two types of inferences: inference-for-oneself and inference-for-others. So what this would mean in essence is that when we are involved in a debate and want to convince someone else that a sign is a valid sign, then the structure of the three conditions is in the form of an argument. And when we use the same argument to help us make an inference for ourselves, then the argument is a judgement, a judgement about inference. Thus, although the three conditions are pre-Dignāga, the transition from debate to 'private inference' is an important step.[15]

3.5 *Dharmakīrti*

Dharmakīrti (c. 600 AD), in *Nyāyabindu*, suggests three broad divisions into which inferences can be grouped based on (1) own-nature, (2) causal relation and (3) non-perception. All three are not only interesting in their own right but are also kinds that can be discerned in scientific inference. The relation to science is further strengthened when we understand that the two kinds of inference based on own-nature and causality are dependent on the notion of natural relations and the presence of 'natural' properties. As Matilal notes, for Dharmakīrti what makes an inference valid is 'that it deals with what may be called, in some sense, genuine properties.' Matilal goes on to add that Dharmakīrti's claim is that 'if we know either of the two natural relations, identity

and causality, we have a sufficient guarantee for making such universal claims as "all Fs are Gs".'[16]

The first kind, namely, inference based on *own-nature* is illustrated with this common example: This is a tree because it is an oak tree. Considering that Dharmakīrti also used the term identity to describe this relation, it seems clear that this kind of inference is based on identifying the oak tree *necessarily* with a tree. This example also suggests, as others have pointed out earlier, that the inference is 'based upon the relation of class inclusion' and can be seen as an analytical statement. What is interesting here is the relation of analyticity with inference. For Kant, analytic statements are those in which the predicate is already contained in the subject as, for example, in the statement 'The green apple is green'. Analytic statements are necessarily true and do not depend on the world or experience for their truth. They are logical statements in that they are only required not to be self-contradictory. Kant does not formulate these statements in the context of inference. When one sees a green apple, do we infer that it is an apple or that it is green? The idea that there is inference in analytic statements is an interesting one, especially given the fundamental idea that inductive inference increases the knowledge content. On the other hand, it can be argued, as Prasad does, that the own-nature kind of inference does not make any 'epistemic progress.'[17] Further, he argues, that in these kinds of cases there is no *hetu* or reason from which we can infer a property. He, therefore, concludes that this mode of inference, if we call it inference, is deductive in nature.

There are many interesting issues here. Why is it important for Dharmakīrti to call these kinds of conclusions as inferences? We need to remember that inference not only makes 'epistemic progress' but it also arises after perception. What is it in perception that does not allow us to 'see' an oak tree as a tree? I think Prasad's analysis misses the point about this kind of inference. The point is that the statement 'This is a tree because it is an oak tree' is trivial (and not

inferential) only if the term tree has the same connotation in both the places where it occurs in the statement. However, I suggest, the use of the same word tree should not lead us into the mistake of believing they are both referring to the same thing. At the perceptual level, an oak tree is a tree. But what if the term 'oak tree' is referring to the real tree which is being perceived, whereas the word 'tree' in the same sentence refers to the idea of a tree or a concept of a tree? Now, in this case, there is no triviality in saying that 'This oak tree is a tree'. In fact, there is epistemic progress when viewed in this manner because we are able to add a conceptual idea to a real entity. The point about linguistic usage, which is also a very important theme for the Buddhist logicians, must also make us aware that the tautology of the analytic-like statement only hides a more interesting meaning.

The second kind of inference is the more common one and is based on causal relations. The common example being, 'There is fire here because there is smoke here'. Here, smoke and fire are linked by a causal relation. Fire causes smoke and there is no possibility for smoke to be present if fire is not there. So, when we see smoke we infer the existence of fire. In general, from seeing a thing (as effect) we infer the existence of its cause. This is an important kind of inference which covers many common inferential cases. The difficulty in this kind of inference lies in the definition of causality and in knowing the cause. For the Buddhists, the cause is that event which is immediately prior to the effect and makes the event possible in the same location. The important distinction to note is that in Dharmakīrti's formulation, cause, like identity, is a natural relation. That is, it is in the *nature* of smoke that it is caused by fire and it is the knowledge of this natural connection that is exhibited in this inference.

The emphasis on the nature of causal relation might suggest the similarity of this kind of inference to the first kind based on own-nature of reason. But this cannot be known until we resolve the problem of knowing which comes first:

Do we know the natural relation of cause and effect from the inference we make or do we make an inference once we know the natural relation? It seems to be that the cause–effect link is known empirically. So, given the problem of induction, how is it possible to be certain about the inference of the cause from seeing the effect? One answer is to say there is a natural relation between smoke and fire. This is like the causal relation in a scientific law. However, there is a problem with the causal relation described by Dharmakīrti. In the examples that are discussed, it seems that only a single causal factor causes an effect. In this sense, the emphasis on a single causal condition or factor is reminiscent of Mill's Methods (see Chapter 4). Although this view of causal action is close to the Buddhist view of cause mentioned above, basing the analysis on a single causal factor, as Prasad points out, dilutes the strength of this inference. Further, he argues that a necessary relation makes Dharmakīrti's kinds of inferences into deductive inferences and therefore non-ampliative, and thus incapable of yielding new knowledge.

The third kind of inference is a unique one based upon non-perception. A commonly cited example of this type is 'There is no pot here because no pot is perceived here.' The basic idea here is that we make inferences based on non-perception. This means that not all our inferences arise from positively perceiving something. Non-perception of various factors is also a cause for inference. For example, the very fact of not seeing smoke (in a situation when you expect to see it) makes us infer something. Dharmakīrti goes on to give eleven varieties of inference from non-perception.

Just like the first two types of inference, identity and causal relation, this third type of inference based on non-perception also has a notion of necessity. This idea of necessity arises from the condition that if an object has all the conditions for its perceptibility then it should be necessarily perceivable. In fact, this necessary perceivability will be its essential nature, somewhat similar to the first type of inference.

Now, if something is perceivable and all conditions for its perceivability are present but still we do not perceive it, then we can infer that it is not present there. Thus, non-perception becomes a reason, *hetu*, for an inference about non-existence. Why is this an inference? Does not all non-perception imply non-existence? The simple answer to this is that there are a host of things which we do not perceive, which by their very nature are not perceivable. Prasad gives examples of ghosts, God or even a virus.[18] In these cases, just because we do not perceive them, we do not infer that they do not exist. Once we understand that non-perception is actually a condition for something else, we can see why Dharmakīrti tries to logically develop this mode of inference. If there is an inference from non-perception, then Dharmakīrti has to show that it fits the triple condition of inferential signs. However, it seems to be the case that all the three conditions are not relevant for this inference. Prasad makes the observation that for this inference only the first condition is really needed, and argues that this makes non-perceptual inference analytic and deductive.[19]

There is a potential for seeing this mode of inference as being trivial. One may understand this as saying that when an object is not perceived at a particular location we infer that it does not exist at that location. Not only does this statement seem trivial but it is also circular since I can explain the non-perceptibility of the object by saying that it does not exist there. In one sense, the inference reduces to explanation of the fact that the object is not perceived at a location. (The Naiyāyikas would claim that they perceive absence and so do not have to infer it.) An inferential cognition of this would be: I do not see the object and hence infer that the object is not there. But surely Dharmakīrti is not guilty of this naivety! The crucial point that makes this an inference is the observation that given all conditions that would have made the object to necessarily exist, it still does not exist. And this is an important formulation. For example, if I do not see a tree in my kitchen I do not infer that there is no tree

in the kitchen. I explain the fact that I see no tree in the kitchen by saying that it is because there is no tree there. On the other hand, if I do not see a stove in the kitchen, I am puzzled. It is not enough to say that there is no stove there and therefore I do not see the stove. I am puzzled because I expect a stove in the kitchen—this is almost the necessary definition of a kitchen—and given this I am surprised that there is no stove. In fact, I will be moved to ask the question: how is it that there is no stove in the kitchen? Thereby emphasising that not only am I aware of the absence but also demand an explanation for this absence.

We can immediately notice that such an inference is based on prior knowledge we have about the object and the necessary conditions for its existence. In the modern context, it is similar to what happens when an experiment is conducted. Let us say the experiment is set up and all conditions are ready for a particular phenomenon to occur. And then we notice that the expected event does not happen. From this, what can we infer? We can infer that the conditions are not sufficient for the event to occur or that if the conditions are indeed sufficient then the event is really non-existent there. Dharmakīrti is concerned about the latter inference since the necessary conditions for an object's existence are all supposed to be present and yet the object is not present. Note that there is certainty about this conclusion and there is no ambiguity about whether that object is there or not. For example, suppose I do not perceive a stove in the kitchen because it is smoky. Given this non-perception I cannot say with any certainty that there is no stove in the kitchen. What allows me to assert with certainty that the object is really non-existent at a particular location is to have all the right conditions for perception and yet find that the object is not perceived.

I believe that the importance of this formulation lies in our capacity to extend it to cases not considered by Dharmakīrti. Science offers some of the best examples of this. The basic importance lies in the possibility of inferring from absence

and non-perception, a worldview which is unique in Indian logic in that absence is a very important category for them, especially the Naiyāyikas. Science describes a world filled with invisible entities many of which are 'perceived' through the use of instruments. However, we do not directly see through instruments; we need to infer what exists and what does not exist from instrumental data. For that we use theories to make sense of what we see. These theories, in general, describe the necessary conditions that enable our awareness of the existence of a phenomenon. Non-perception, given the right conditions, is actually like falsification. The example of null results is very important for inferences. Experiments in science infer a lot of useful information from null results. Thus, the importance of this type of inference is not only for non-perception of objects but also for 'non-perception' of 'concepts'. That is, we can extend this argument to various cases where non-perception is with respect to terms such as hypothesis and concepts. Having said this, we need to note that an important problem in this kind of inference is the possibility that we may not be able to know what constitutes all the necessary conditions for perception of a particular object/event.

Dharmakīrti gives eleven types of inference from non-perception. I think it is instructive to consider them briefly, at least for the richness of ideas about non-perception.[20]

1. *Non-perception of the essential nature of the property.* The example for this is non-perception of smoke because one does not see a body of smoke, which is otherwise perceptible. Prasad interprets this type as 'A thing's non-perception as the logical reason for its non-existence.' As discussed in detail earlier, this is not a trivial case of non-perception. The point is that once all conditions for a particular perception to occur are given and if, under these conditions, there is no perception, then there is non-perception of the perceptible object. Matilal notes a psychological condition of the person looking for the perception in this variety of non-perception. In experiments, one is always looking to perceive some thing or

the other. There is a definite psychological element in experimental observation and perception.

2. *Non-perception of an effect as the logical reason for the non-existence of its cause.* Example: there are no causal factors for smoke here, because there is no smoke. Here too smoke is not perceived like in the first case. But from this same non-perception we have a different inference in this case, namely, that the causal factors which cause smoke are absent. Of course, this does not mean all the causes or causal conditions are absent. The specific cause that is inferred to be non-existent is arrived at by the condition of this inference that the cause should have had an 'unobstructed capability' to produce the effect, in spite of which the effect is not perceived.

3. *Non-perception of the pervader-property or the non-perception of the inclusive as the logical reason for the non-existence of a thing included in it.* Example: it is not an oak because it is not a tree. We know that oak is included in the class of trees. So when we do not perceive a tree at a particular location, we can be sure that there is no oak at that location.

4. *Perception of what is contrary to the essential nature of an entity/cognition of the opposite of that whose non-existence is inferred.* The example for this is there is no cold touch here because there is fire here. Reason in this example is fire and the inference is that there is no cold touch where the fire is. At first instance there seems to be no inference from non-perception in this case. However, there is an inference of a negative proposition that 'there is no cold touch' from a positive example of fire being present.

5. *Perception of the contrary effect/cognition of an incompatible effect.* The example for this is there is no cold touch here because there is smoke. Here the reason is smoke and smoke is caused by fire, which opposes cold as in the previous example. So, if we see smoke we can infer that the place where the smoke is will not be cold. The inference made here is about the absence of cold.

6. *Perception of the entity that is pervaded by what is contrary to the entity/cognition of something pervaded by the opposite of that whose non-existence is inferred.* The example for this is that it is not the case that a created entity would not be destroyed for certain, for it depends upon another cause.

7. *Perception of what is contrary to the effect.* The example for this is that there is no source of cold because there is perception of fire. Here there is a denial of something, 'source of cold', because this is incompatible with the effect of fire, which is perceived. Prasad gives the form as follows: there is no x, because there is y and y is the antagonist of z, an effect of x.[21] The inference here is not the simpler one of saying there is no cold here because there is fire (this is what the fourth case is) but there is no source of cold. So x is the source of cold, y is fire and z is the cold, which is an effect of the source of cold.

8. *Perception of what is contrary to the pervading property/cognition of the opposite of the denied's genus.* The example for this is there is no cold touch from snow here because fire is present. Here cold touch is denied, the genus for this cold touch is snow and this denial is possible because what is perceived, namely fire, is contrary to the genus snow, which subsumes cold within it.

9. *Non-perception of the cause/non-cognition of the cause.* The example for this is there is no smoke here because no fire is perceived. This is the inference of the non-existence of effect, smoke, from the non-existence of the cause, fire.

10. *Perception of what is contrary to the cause/cognition of the opposite of the cause.* The example for this is that a person does not have anything like horripilation, etc., because there is fire near him which has a special kind of capability. Here the conclusion is a denial and the reason for this denial is because of the perception/cognition of the 'opposite of the cause of what is denied'. That is, the cause for horripilation is cold, and seeing fire (of a particular kind) that is the

opposite of the cold which causes horripilation, we can infer that there will be no horripilation in this case.

11. *Perception of the effect that is contradictory to the cause/cognition of the effect of the opposite of the cause of what is denied.* The example for this is this place does not have a person who is suffering from horripilation because a body of smoke is perceived here. Like in one of the earlier cases, smoke implies the presence of fire and the reason in the last example follows from this point.

It can be argued that all these eleven forms are not independent of the other two kinds, namely own-identity and causal nature, mentioned by Dharmakīrti. For example, Prasad points out that almost all these cases are reducible to the causal type or to the identity type of inferences. However, even if this is so, this classification is important because it is a complex and sophisticated analysis of the common types of inference we routinely make from non-perception. Moreover, the use of such inferences in scientific reasoning makes it an interesting analytical tool, especially when we consider the paucity of such analysis of non-perception in the mainstream Western traditions.

What we see in this brief description of the Nyāya and Buddhist theories of inference is an attempt to rationally analyse the nature of reason without dissociating it from the nature of the world. To critically establish these theories, Indian logicians draw upon many different concepts, some of which will be discussed in more detail below. One of the common critiques against drawing upon older philosophical traditions is that the examples these logicians considered were too simple and are not relevant for our modern world. But as we have seen in the examples discussed by Dignāga and Dharmakīrti, the scope of the examples is much wider than the common smoke–fire example. Sometimes, the consideration of such examples is dismissed as being not representative of much more complex structures of thought that apparently inform modern thinking. To give into this

view would be to unnecessarily privilege contemporary thought processes, although this should not be taken as a support for the absolute truth of earlier philosophers. The point we have to consider is that many of the inferences we make in our lives today, both in our day-to-day activities and in specialised activities such as science, are similar to the ones discussed for ages, both in the Western and Indian civilisations. While new concepts are definitely needed to extend various ideas in Indian logic, and philosophy in general, it is also the case that some foundational problems considered by these philosophers still demand satisfactory responses. It is true that we do not have to analyse inferences such as those given by the example of smoke and fire, but it is important to note that more complex inferences we make, say in science, are actually made up of these kinds of inferences also. We might have more complex chains of inference but the analysis of the basic components would still benefit from newer perspectives.

The debate between the Buddhists and Naiyāyikas continued over the centuries. This fertile interaction catalysed new concepts as well as refined many fundamental concepts in logic and epistemology. Logical ideas were sharpened in these debates, which included proponents of other traditions such as the Vedāntins as well. The next significant change in the conceptual formulation happened in the development of Navya-Nyāya, referred to as 'new logic'. It has been observed that Navya-Nyāya is closer to modern logic. Although some suggest that Udayana (c. 1000 AD) should be seen as the initiator of this school, many others place Gaṅgeśa (c. 1300 AD), the author of the most influential treatise, *Tattvacintāmaṇi*, as the originator of this school. Gaṅgeśa not only compiled many of the earlier ideas in the tradition but also developed on them. Some of the refinements are of central philosophical importance and modify the understanding of concepts such as pervasion, property, relation, universals and so on.

3.6 *General Differences between Indian and Western Logic*

Matilal identifies three essential differences between Indian and Western logic.[22] Firstly, epistemology and logic are not strictly demarcated. This relation between epistemology and logic, so integral to Indian logic, is what is erased in Western logic, since it is based on the belief that epistemology (based as it is on the contingent) must have no relation with logic (based as it is on the necessary). In the Indian case, inference is actually a *pramaṇa*, a valid means of knowledge. It is one of the sources of knowledge in all Indian traditions except the materialist Cārvākas. This is also the reason why the notion of evidence is so important in Indian logic. As we saw earlier, evidence and reason are often used synonymously in analysing valid inference. In the Western tradition, it is well known that deductive structures are independent of the truth of the premises. Thus, it is commonly observed that logic is indifferent to the truths of the world, the set of empirical truths. In fact, what sets Western logic apart is this indifference to the dictates of our world. But this is where Indian logic significantly departs from Western logic. The use of the example in the *nyāya* five-step process and the similar and dissimilar conditions in Dignāga's formulation illustrate the importance of factoring in empirical truth as part of the logical process. This does not mean that there is no formal argumentative structure which can be discerned in Indian logic, and such analyses are available in the literature.[23]

The rejection of empty referring terms is another indication of the essential connection between epistemology and logic. For example, one of the premises in Aristotelian syllogism could well be 'All Martians are blue'. This would be a valid statement in the syllogism independent of the question whether there are Martians and whether they are really blue. For Indian logic, such a premise is not allowed unless there is some empirical evidence for the same. Now, one might argue that this is exactly the reason why we have logic so as to transcend the empirical restrictions arising from the real

world. Logic helps us to order empirical facts and so has to be beyond these facts. Even if this is so, we can understand Indian logic as showing how there can be logical structures, without letting go of a commitment to truth and knowledge as part of logical argumentation.

The real problem would arise only if it is claimed that empirical truths *dictate* the logical structure. This is a view that is not found in the dominant traditions of logic in India. As we have seen, they acknowledge the logical process present in moving from some premises to a conclusion, but they do not say that these empirical truths dictate the kind of arguments that are possible. In fact, it is useful to see the empirical and epistemological content in Indian logic only in terms of a regulative factor and not as a determining factor. Thus, among all possible statements in a logical argument some are disallowed. Empiricism and issues of epistemology are ingrained into logic in so far as they are used to delimit the possible range of logical arguments. The many attempts, with varying degrees of success, of rewriting Indian logic in terms of formal and modern symbolic logic only point to the essential logical structure of Indian logic. The epistemological component can be understood as regulating the possible logical structures that are allowed rather than make the process illogical. This insistence on a regulatory mechanism might suggest that the Indian logicians were suspicious of reason which has no grounding in the real world.

The second difference which Matilal notes has to do with the presence of psychological elements in Indian logic. It is precisely the removal of psychology from logic that distinguishes logic in the modern Western logical tradition. So, if Indian logic retains these elements then it is either a fallback to ancient logical systems or worse, not being aware of an essential character of logic. Matilal counters this by saying that the Indians did not commit the bigger blunder of emphasising psychology in logic thereby leading to psychologism. One can also understand the Indian 'psychologised' logic as a different kind of logic, a position

that can be reasonably held when compared with the many kinds of logic today including logics of game theory, decision theory and so on. But there is another argument that we can invoke here and this has to do with the relation between logic and psychology.

It is well accepted that Indian logic shows explicit psychological elements. Let me discuss Mohanty's detailed argument in this context.[24] First of all, there is an explicit psychological description of the process of inference, starting from perceiving a sign (say smoke), then remembering the connection between smoke and fire, which then leads to an awareness that this connection is applicable to the present case, and finally leading to the inferential cognition. Furthermore, the psychological dimension is explicit in the invocation of desire (either absence or presence of) as a condition for inference. However, the inferential schema that is used to explain either inference-for-oneself or inference-for-others does not carry over the consequences of the psychological description. In some sense, this is like the description of any rational, objective act, which is dependent on some mental process but whose content is independent of the consequences of a subjective, psychological act. For example, even in the creation of scientific theories, ideas arise through a cognitive process which can be described in terms of psychological terms, but the content of the theory is objectively accessible. Inference-for-oneself is only based on the recollection of the connection between smoke and fire, whereas inference-for-another needs the five-step process described earlier.

The argument that Indian logic is psychological also depends on what is meant by the psychological. If being psychological implies an essential dependency on the subjective experience, then Indian logic is definitely not psychological, especially because even while using the language of psychology it still deals with and exhibits universal structures of human thought. The greater challenge to the logical character of Indian logic actually would come from

the entanglement of the empirical within the logical, but as we have seen above this too is not a significant problem. As Mohanty also notes, *tarka* is a good example of a formal, logical (deductive) structure and does not mention or use examples. So, it is not that formal logical structures were unknown to Indian logic; more importantly, the use of examples as part of inferential reasoning does not negate its formal character in the sense that it does the work that formal structures do. We can thus understand the use of example along the following lines suggested by Mohanty: one, because the example should be one that is acceptable to others, it not only dealt with true premises but it also served an important role in the 'dialogical-disputational context'; two, because of the insistence on the truth of the premises, the example preserves the 'epistemic purity' of the inference; and three, an example succeeds in introducing 'an individual by the rule of existential instantiation.'[25]

There are other important points of difference, details of which I will not go into here. These include the idea of the necessary in Indian logic and whether this logic is intensional or extensional. We also have to remember that whichever type of logic we choose, we are making commitments to some underlying worldview; in the case of Western logic, there is a commitment to the existence of abstract entities such as propositions. Now, whether it is better to make this assumption as against what Indian logic does is a question that cannot be resolved by logical arguments alone! Mohanty in the conclusion of his essay on Indian logic notes that Western logic is framed by oppositions between logical and the empirical, necessary and contingent and so on, and that Indian logic, taking a middle path, shows that 'we need not treat the logic and the psychological, the epistemic and the causal, the extensional and the intensional as though they are irreconcilable opposites.'[26]

Thirdly, Matilal notes that mathematics profoundly influenced Western logic whereas in India, it was grammar that was most influential. Although he does not explain this

point further, there are two observations that we can make about this influence. Firstly, in what sense was mathematics a model for Western logic? There is a commonality between mathematics and logic in the emphasis on the idea of 'Forms', which were very privileged entities for Plato. In fact, the step of considering premises without any empirical or truth content as part of valid logical reasoning is a consequence of privileging the notion of form over content. Thus, the influence of mathematics on logic is most clearly seen in the importance given to valid forms. Moreover, mathematics was also seen as a model of deductive certainty, which was universally applicable and so on. All these characteristics of mathematics (specifically of geometry and early arithmetic) were transplanted to logic.

Matilal notes that, in contrast, grammar was the dominant influence on Indian logic. There are two comments that are relevant here. Firstly, Indian mathematics was itself quite different in character compared to ancient Greek mathematics. The emphasis was not on models and axioms but on algorithms and pragmatic use. Mathematics, especially as used in astronomy, was built not from axioms but from algorithmic rules based on manipulations to get the best results for practical use. This pragmatic, result-oriented character of Indian mathematics is part of a larger worldview which it shares with the pragmatic, empirically-oriented character of Indian logic. So, I believe that it can be argued that both Western and Indian logic were influenced by mathematics, except that what each took from mathematics depended on the dominant nature of their respective mathematics.

Secondly, Matilal's point that Sanskrit was the dominant influence in Indian logic also indicates a relation between Indian logic and mathematics. Sanskrit is a highly structured language with more similarity to a formal language like mathematics, especially in comparison with natural languages like English.[27] Therefore, being influenced by Sanskrit instead of mathematics (of the Greek variety!) is already to be

influenced by a system that is close to the mathematical. Given these arguments about the nature of mathematics and of the special nature of Sanskrit, it seems reasonable to believe that explaining the difference between Indian and Western logic as one between mathematics and grammar might not be too illuminating. However, this does not mean that the special characteristics of Sanskrit are not reflected in Indian logic. The language of Indian logic is indeed conditioned by the peculiarities of Sanskrit.

The last difference mentioned by Matilal is the lack of a distinction between induction and deduction in Indian logic. I discuss this point separately below since it is also an important theme in philosophy of science.

3.7 *Summary of Themes in Indian Logic Relevant to Philosophy of Science*

In what follows, I will summarise some of the important philosophical themes that are essential to Indian logic. There are other philosophical ideas which I do not discuss here; the choice I make is based on what I believe are potentially relevant themes for philosophy of science. Some of the concepts related to Indian logic that I have not discussed here are empty terms, fictional terms and so on. The first topic that I begin with follows from the observation that Indian logic does not distinguish between deduction and induction but uses both of them as part of its logical structure. Given the importance of deduction and induction in the history of philosophy of science, the brief discussion that is given here might serve as a general introduction to this debate. The other special themes that I discuss are: pervasion or the invariable concomitance relation, *tarka* or *reductio ad absurdum,* undercutting conditions, fallacies, universal positive and negative signs, definitions and the nature of properties in Indian philosophy. Each one of these topics is vast and complex, and the summary I have chosen to give is only an indication of some fundamental ideas about them. I see this

material as mere indications of different conceptual themes in Indian logic that might be of potential use for philosophy of science.

3.7.1 *Induction and Deduction*

It is not surprising that one of the common comparisons made between Western and Indian logic is the distinction between induction and deduction. In Western logic, deduction and induction are not just different in character but are also associated with different conceptual worlds. Deduction is associated with certainty and its formal structure is not only independent of the world but also of the truth of its premises. It has been argued that deduction is non-ampliative inference in that no knowledge that is not already present in the premises can be found in the conclusion. Induction, on the other hand, is characterised not only by an ampliative character (conclusion has more knowledge than is available in the premises) but also by the uncertainty of its conclusions. In the next chapter, I will discuss these two kinds of arguments in more detail with special reference to the role they play in science.

It is not a surprise that when Indian logic was compared with the Western models, the deduction/induction distinction was at the core of many disagreements. The first point is that, as Matilal notes, there is no such clear distinction in Indian logic, whereas for Western logic this distinction is at its foundations.[28] The lack of this distinction adds fuel to the charge that Indian logic is not really logic. In order to exhibit that Indian logic too was in some sense based on such structures, many attempts were made to rewrite the Indian inferential process as deductive syllogisms. One of the common reconstructions is the rewriting of the *nyāya* five-step process as a deductive syllogism of the form: 'Where there is smoke, there is fire; Smoke; Therefore, fire'. The problem is that, strictly speaking, inferences in Indian system are about particular cases and its conclusions are singular

inferences. That is, the inferences are about a specific hill (indexed by this hill or the yonder hill) and the conclusion is about a specific property which the hill is inferred to possess. Even so, the above standard inference has been written to indicate its similarity to Aristotelian syllogism in this manner: 'Wherever there is smoke, there is fire; there is smoke on the yonder hill; therefore, there is fire there.' Matilal notes this is better expressed by adding the phrase 'as in a kitchen' at the end of the first premise as follows: 'Wherever there is smoke there is fire, as in a kitchen.'[29]

However, it might seem that these are artificial means to modify Indian logic to fit Western logic. The fact that philosophical themes in Indian logic differ crucially from its Western counterpart adds to the legitimacy of this complaint. Nevertheless, the issue is whether there is something common to logical processes in both these logical systems and the answer must be in the affirmative. In addition, we could say that Indian logic demands not only validity but also soundness. In fact, I believe that the confusion is exaggerated by the attempts to look at the *nyāya* five-step process in terms of syllogisms. For, as I argue in Chapter 5, this process functions quite similar to the deductive–nomological model of explanation. The deductive structure is already present in this form of explanation and thus the *nyāya* process is essentially deductive.

But the more interesting distinction lies in the way inductive inferences are treated in Indian systems. In the Indian context, as should be obvious from the discussion above, inductive inferences were very commonly analysed. The question about induction and certainty is also a common theme in both Indian and Western systems. Whereas Hume acknowledged defeat, the Indian logicians waged a long battle against scepticism about induction, leading finally to complex formulations of pervasion or invariable concomitance. Matilal notes that Indian arguments about induction are similar to J.S. Mill's theory of it and suggests that Mill's method of agreement and difference is similar to Dignāga's triple

conditions for valid inference.[30] I discuss Mill's methods in detail in the next chapter and will analyse Indian logic and Mill's methods in the context of science there. I believe that it is much more useful to compare how science responds to the challenge of induction and how Indian logic deals with it, since both science and Indian realist philosophies share common concerns. The section below on invariable concomitance also indicates the way induction was dealt with in Indian logic.

3.7.2 *Pervasion or Invariable Concomitance (vyāpti)*

The idea of pervasion or invariable concomitance, called *vyāpti*, is perhaps one of the most important ideas in Indian logic. The basic formulation of *vyāpti* is quite simple. Consider the example of smoke and fire. When we make an inference of the form, 'Where there is smoke, there is fire', what we are basically claiming is that smoke and fire always go together. This is what is meant by saying that smoke is pervaded by fire. This pervasion relation is also called the relation of invariable concomitance. What is so special about this relation? The importance of this relation arises from the fact that there are many pairs of properties that go together just like smoke and fire, but they do not have to be necessarily related. For example, let us assume that whenever somebody sees me I am wearing a particular shirt. Seeing this occurrence, this person might inductively conclude that the particular shirt and me are in a relation of invariable concomitance! What is the difference in the relation between my shirt and myself, and smoke and fire?

One immediate answer is that there is a necessary relation between smoke and fire whereas there is no similar relation between the shirt and myself. What this means is that smoke cannot exist without fire whereas I can exist without that shirt (although there may yet be no evidence of this). But what does it mean to say that it is a necessary relation? How do we understand the meaning of the word 'necessary'? One

possible response would be to say that fire causes smoke and therefore there is a notion of causal necessity in this case. But causal relation cannot explain the meaning of necessity since this relation itself needs explanation. Hume's famous argument that casual relations are no more than contingent occurrence is well known. From the statement that A causes B, Hume would say that we can only say that A and B always occur together and for an empiricist there is no reason to claim that there is more to causality other than this appearance. A well-known example of a non-causal contingent appearance is that of day and night which always follow one after the other but neither of them causes the other.

In the case of concomitance, the first point to note is the fact that two things occur together, like smoke and fire. Firstly, why do we think they occur together? This conclusion is based on perception of some instances where whenever we have seen smoke we have also seen fire. So, the statement that 'where there is smoke, there is fire' is a generalisation of this common empirical observation. This generalisation is an inductive generalisation where from a few observed instances we make a general statement about this occurrence that is applicable to all places and times. There is no problem with making inductive generalisations per se. What is problematical is to accept the inductive generalisation with any measure of certainty and it is precisely this certainty that Indian logicians were aiming for.

Pervasion or invariable concomitance is the observation of two properties occurring together. It is also extended to the conceptual domain, as in the statement: nameability pervades knowability, which is another way of saying whatever is knowable is nameable, which is another way of saying that wherever knowability is 'present', nameability is also 'present'. Pervasion is not a symmetrical relation. For example, fire pervades smoke, meaning thereby that wherever there is smoke there is bound to be fire but not the other way around. We cannot say that wherever there is fire, there is

smoke since there could be fires (like in a metal) which create no smoke. So, fire pervades smoke, smoke is pervaded by fire and smoke and fire are in the relation of pervasion. Day and night, for example, do not show a pervasion relation. The central concern for Indian logicians was to know with certainty which relations are pervasion relations. These questions are framed mostly in the context of inference since the very possibility of valid inference in Indian logic seems to be based on the recognition of some kind of pervasion relation.

Dignāga's triple condition for a sign is one way to approach this issue. As we have seen, Dignāga's conditions attempt to demonstrate with certainty whether a sign always occurs with another sign, for example, whether fire always occurs with smoke. For, it could be the case that it is just an accident that whenever we have seen smoke we have also seen fire. To infer that wherever and whenever we see smoke we are justified in claiming there is fire in that location would mean that we know something more about smoke and fire other than just seeing them together a few times. Dignāga's second condition does not help in giving us certainty because it only cites various similar cases where the two properties go together. The third condition is very important just for this reason because it requires that the property which is pervaded cannot occur without that property which pervades it. This condition which states that the sign must not occur in dissimilar cases essentially is saying that the property which is the sign for some other property must never occur in a place where the other property is not present.

The great challenge is then to frame this requirement properly. It is not enough to say that the sign must not occur in any location where the property by which it is pervaded is absent. Such a condition would again be dependent on an inductive generalisation because even if it does not occur in a few places where the inferred property occurs, how would we know that it will be so in all the places? So, the Indian logicians phrase this condition in various ways, many of which

deal with the notion of absence. This is not only an interesting intellectual exercise but also one which has great significance to understanding the notion of absence.

One way to phrase the third condition is to say that where fire is absent, so will smoke be absent. But this statement by itself is impossible to confirm because there will be many places where there is no fire and no smoke but these places may have nothing to do with fire or smoke. The problem with absence is that the places where fire is absent also manifests the absence of countless other properties. So, for example, someone could see the absence of red colour in a particular location and say where there is no red colour there is no smoke. This is reminiscent of the confirmation problem. What confirms the statement that 'all ravens are black'? It seems clear that all ravens which are black will confirm this statement. And a raven which is not black will immediately disconfirm it. But, as is well known, the statement that all ravens are black is logically equivalent to its contrapositive which is that all non-black things are non-ravens. This latter statement is confirmed by all non-black things, such as red book, white shoe and so on, since these are also non-ravens. And it seems absurd to think that red books and white shoes can confirm the statement that all ravens are black.[31]

Similarly, just stating that smoke does not occur where fire does not occur is not enough because the induction problem will still be present in this case. The dissimilar cases are those locations where no fire *should* be present, because of the nature of these locations. For example, a lake, which is a body of water, cannot have fire because water is contrary to fire. Now, if we see smoke coming out of a lake then it means that smoke is not necessarily connected to fire. The dissimilar case is one step better than just saying locations where fire is not present, smoke should not be present, because we are now considering only those places where fire *cannot* be present because of the essential contrary natures of that location and fire. Now, suppose we find that there are some dissimilar cases where smoke is not found.

While this increases our confidence in the relation, how can we have certainty that smoke and fire are invariably concomitant? Furthermore, is there a relation between the absence of smoke and the absence of fire just like the one which exists between smoke and fire?

These comments are mainly to explain why Indian logicians gave convoluted expressions for invariable concomitance (*vyāpti*). Nyāya has a long history of attempting to clarify this concept in its most general sense, culminating in very complex ways of articulating it in Navya-Nyāya. I will briefly consider some of the ways in which *vyāpti* has been defined in order to illustrate the kind of philosophical issues that are related to it. I believe that some of this analysis of the nature of *vyāpti* is important for an analysis of necessity and in particular, the necessity present in universal laws which order empirical phenomena. Thus, *vyāpti* as a concept is potentially very useful for understanding the nature of *scientific laws* through the rubric of Indian conceptual schemes.

While Dignāga's formulation is extremely influential, Dharmakīrti believed that invariable concomitance is grounded in these two forms of inference: own-nature and causal. Own-nature can be used to describe pervasion in the following manner: If B is pervaded by A it could be because B is the essential nature of A. The second kind of inference is the one based on natural causal connection where perceiving the effect (smoke) we infer its 'natural' cause (fire). This reduces to, as Matilal notes, the observation that the essential nature of smoke is to be caused by fire.[32] But the problem, as the Naiyāyikas pointed out, is that many common inferences cannot be explained by Dharmakīrti's types of inference. Later, Trilocana defined *vyāpti* as a natural relation, where by natural he meant 'unconditional' relation, that is, a condition which has no *upādhi* (see section below on *upādhi*).[33] The notion of *upādhi* (or undercutting condition) proved to be important in subsequent definitions of pervasion. Thus, *upādhi* was seen as a negative mark of pervasion.

Gaṅgeśa discusses five definitions of *vyāpti* and rejects

them. It is instructive to consider the salient points of these definitions, especially in the context of understanding the notion of necessary relation. Pervasion is:

1. The non-occurrence of the sign (smoke) in the locus of the absence of the inferred property (fire).
2. The non-occurrence of the sign in the locus of the absence of the inferred property, provided the locus differs from that in which this property occurs.
3. Not having a common locus with a mutual absence which has the locus of the inferred property as its counter-positive.
4. The counter-positiveness of the absence which occurs in all loci of the absence of the inferred property.
5. The non-occurrence in (a locus) other than that which the inferred property possesses.[34]

The first definition is that smoke and fire are in a pervasion relation if in the locus of the absence of fire (that is, in all those places where fire is not there) there is also an absence of smoke. Thus, the relation is defined through absence and not, as inductive arguments generally do, through positive instances such as where there is fire there is smoke. Gaṅgeśa rejects all these five definitions on various grounds including the common one that all of them are based on the absence of the inferred property and hence cannot accommodate the case of ever-present property. He then proposed a definition which is: 'Universal concomitance is the co-existence (of the *hetu*) with the *sādhya* which is not limited by the determinant of counter-positiveness (...) of such an absence as is non-coexistent (...) with the counterpositive and co-existence with the *hetu*.'[35] (*Hetu* is the sign and *sādhya* is the inferred property.) As Chakraborty notes, this reformulation has the advantage of understanding absence of something as 'non-co-existent with its counterpositive.'

It might seem that pervasion can be first conjectured when we come across many instances where a relation is

noticed. But for Nyāya, pervasion is not necessarily only an extrapolation of many instances. It is possible to infer a pervasion even from one instance. For example, from seeing a horse and a cow, we know immediately that a horse is not a cow and thus they are negatively pervaded, meaning thereby that 'whatever is a cow is not a horse and conversely.'[36] Although I do no justice to the extensive literature on pervasion in this short summary, I hope to have given some insights into the philosophical traditions which spent generations fine-tuning concepts such as pervasion. The potential use of such a refined intellectual exercise for contemporary philosophy should be obvious.

3.7.3 *Tarka*

One of the important elements of a larger rational discourse in Indian thought is *tarka*, which is often referred to as *reductio ad absurdum*, suppositional reasoning, counterfactual reasoning, dialectical reasoning and so on. The earliest forms of *tarka* is found in the Buddhist *prasaṇga* style of debate, where the aim was to negate an opponent's claim without necessarily having to generate any positive counterpoints. The difference between *prasaṇga* and *tarka* lies in the sceptic's use of *prasaṇga* to disavow both positions whereas *tarka* demolishes one in order to support the other.[37] *Tarka* is also one of the sixteen categories in the *Nyāyasūtra*. In the early traditions of Indian thought, *tarka* was the term for reasoning. Ganeri notes that in popular use, *tarka* 'is the nearest one gets to a Sanskrit synonym for 'rationality'.'[38] Matilal calls *tarka* hypothetical and indirect reasoning.[39] In the Nyāya tradition, true to its empirical grounding, *tarka* is not seen as a *pramāṇa*, that is, as a valid means towards knowledge, although Uddyotakara is said to have suggested the possibility that *tarka* is like a *pramāṇa* that can yield empirical knowledge.[40] While *tarka* is accepted as a useful device for reasoning, the conclusions based on this form of reasoning are not to be accepted as valid by themselves without further

corroboration, presumably supported by other *pramāṇas.*

The reductio argument is commonly described as *tarka* and a typical example of it is:

> If A were not B then A would not have been C; but it is *absurd* to conceive A as not-C (for it is *inconsistent* with our standard beliefs or rational activity). Hence, A is B.[41]

Nyāya does not accept *tarka* as a *pramāṇa* since it deals with suppositions and counterfactuals. There is no empirical grounding for this reasoning, although one could argue that the very notion of absurdity or inconsistency is ultimately based on our empirical experience.

An example reveals the basic strategy of such arguments, also referred to as confutation.

> Is the soul eternal or non-eternal? Here the real character of the soul, viz. whether it is eternal or non-eternal, is not known. In ascertaining the character we reason as follows: If the soul were non-eternal it would be impossible for it to enjoy the fruits of its own actions, to undergo transmigration, and to attain final emancipation. But such a conclusion is absurd: such possibilities are known to belong to the soul: therefore, we must admit that the soul is eternal.[42]

Bharadwaja notes three common characteristics of *tarka* found in the various Nyāya philosophers. One was the similarity of examples; two such common examples are:

> If there is no fire here, there would have been no smoke as well. If there were a jar here, it would have been visible as the ground is visible.[43]

Secondly, *tarka* is an important method for empirical generalisations. This is what Bharadwaja sees as the essential role of *tarka* for even when *tarka* is used to counter an opponent's argument, it is basically in the context of empirical generalisations. Furthermore, he makes a distinction between *tarka* statements which are counterfactual statements and *vyāpti* like generalisations, which are more like nomological statements.

Ganeri describes *tarka* as suppositional reasoning, a phrase that indicates the nature of *tarka* statements. Such reasoning comes into play when we want to argue for one position against another by showing the absurd consequences of holding the opposed position. This is 'negative' argumentation in the sense that a particular thesis is not proved by this reasoning but only that another thesis is shown to have undesirable consequences. Positive argumentation is based on empirical evidence in contrast to *tarka*. Ganeri further observes that *tarka* is more broad-based than reductio arguments since the undesirable consequences are more than just contradictions. This larger canvas of *tarka* is captured by Udayana's classification of it into five types: self-dependence, mutual dependence, cyclical dependence, lack of foundation and undesirable consequence.[44] Basically, this classification qualifies how or why particular arguments are unacceptable, as for example, cyclical arguments used to prove a particular thesis. The example Ganeri discusses is this: if we suppose that A, then proving A from A is an unacceptable consequence. This actually seems to be a fallacy of reason that is applied to suppositional reason. At first glance this does not seem to have a special connection to the nature of suppositional reason. The other types except the last one can be seen as fallacies as described in the section on *hetvābhāsas*. Suppositions belong to the domain of imagination and to suppose that something could be the case is to project the possibility of thought onto the potential of an object, thesis or reason. However, consistent with Nyāya's realist position, the problem is in knowing what suppositions are even possible. Like the constraints on doubt, so also the constraints on suppositions, and thus on our imagination of possible situations and possible worlds. Ganeri phrases this point as follows: 'The limits of imaginary supposition are the limits of doubt.'[45]

Suppositional or dialectical reasoning (as Phillips refers to it) is an integral part of Western theories of reason. In Indian philosophy, this kind of reasoning has been very

important in trying to understand the nature of pervasion. The relation between *tarka* and pervasion has been criticised most notably by the Vedāntic sceptic, Śrīharṣa, who points out that *tarka* cannot be founded on pervasion nor can it not be founded on it because in the former case it leads to infinite regression and in the latter case it leads to no distinction between valid and invalid *tarka.*[46] For example, to make a statement that 'if there is no fire here, there would have been no smoke' is to make an assertion of the pervasion relation between smoke and fire. Without being aware of this, how would we formulate such statements? And when the Naiyāyikas use *tarka* as an indirect proof to establish pervasion there seems to be some regression involved. Gaṅgeśa answers this charge by saying that all pervasion does not necessarily need *tarka*; only some of them do—those pervasions about which there is still some doubt.[47]

In the context of science, reductio reasoning is quite common and there is little difference conceptually between the reductio reasoning in science and in *tarka.* The attempts to define pervasion through *tarka* (and thus counterfactuals) should remind us of the attempts in philosophy of science to describe scientific laws through the use of counterfactuals. The extended analysis of *tarka*, especially since it is much more than just reductio reasoning, is potentially very useful for philosophy of science.

3.7.4 *Upādhis*

In the above section on pervasion, it was mentioned that the later formulations of pervasion used the concept of *upādhi.* The study of *upādhis* or the 'inferential undercutting condition' is an important part of Navya-Nyāya. The study of *upādhis* is relevant because of its connection to concomitance and its relationship with defeater situations in Western epistemology. As we have already seen, the central issue for Nyāya philosophers was the validity of certain inferences. In attempting to discover the structure of reasoning that leads

us to make valid inferences and thereby know the proper pervasion relation, they develop the idea of *upādhi.*

An *upādhi* is 'an object or property that has a certain relation to other objects or properties.'[48] The definition of *upādhi* is that it is a property which pervades the inferred property and does not pervade the reason, that is, there are cases where the reason is present but the *upādhi* is not. Given this, the *upādhi* undercuts and thereby does not allow the inference of the inferred property from the reason. An example of an *upādhi* might clarify its nature. The standard example of an *upādhi* is 'wet fuel'. This is a property which blocks the inference 'Where there is fire, there is smoke'. This blocking is done in the following manner. The inference in this case is that 'Where there is fire, there is smoke'. So, smoke is the inferred property and the reason is fire. Wet fuel is the *upādhi* and we can immediately check if it obeys the conditions for being an obstruction of the above inference. Wet fuel is found wherever smoke is so the *upādhi* pervades the inferred property. Also, we have fire as in molten metal where there is no wet fuel so there are cases where reason is present but the *upādhi* is not, thus indicating that the *upādhi* does not pervade the reason. Knowing this *upādhi,* we will not make the inference that where there is smoke, there is fire. It has also been pointed out that *upādhi* functions as a defeater as described in Western epistemology.[49]

Another common example is the China rose when its red colour appears in a crystal nearby it. The situation is as follows: one sees a red crystal and thinks that the redness is a property of the crystal but it so happens that its redness is transmitted from the China rose. The point here is that this redness is due to the *upādhi* and not to the crystal. The implications of this are different since it seems as if *upādhi* is a defeater of perceptual cognitions also.

The person who is making the inference (say of fire from smoke) is able to make the connection between seeing smoke and the reason for the inference, which is the statement of pervasion between smoke and fire. This, according to

Gaṅgeśa, occurs through a reflective grasping and is called *parāmarśa.*[50] For Gaṅgeśa, this awareness is the proximate cause for the inference being made, meaning therefore that if this awareness is not present then the inference will not be possible.

Therefore, the question of what causes a particular inference is also dependent on this awareness taking place. Now, if there is something that impedes this awareness, then the inference itself is not possible and thus inferential cognition is 'defeated'. Awareness of an *upādhi* is what blocks the inferential cognition. To find what the correct inferences are, it may be enough to see which of these inferences have *upādhis,* because the presence of *upādhis* is a sign that the inference is not a valid one. Thus, the *upādhis* are called 'undercutting conditions'.

3.7.5 *Fallacies of Reason (Hetvābhāsa)*

An important part of any rational enterprise would be not just to acknowledge that there could be mistakes but to develop ways of understanding what kind of mistakes are possible. The detailed classification of pseudo-reasons, those arguments that look like reasons but are not, illustrates a sustained attempt to find objective measures for reason.

The early *nyāya* theory, as found in the *Nyāyasūtra,* classified fallacies or pseudo-reasons (from henceforth I will use the word fallacy without implying that it is the same as fallacies in Western systems of logic) into five types. These are the erratic, contradictory, controversial, counter-questioned and mistimed.[51] These are types of mistakes associated with the reason term. Recollect that in the five-step *nyāya* process, one of them is the statement of reason which makes possible the inference. There are different types of fallacies related to reason. The *erratic* reason is that which leads to more than one conclusion. That is, the same reason can be used in the five-step process to lead to more than one conclusion. *Nyāyasūtra* explains this occurrence as being due to the lack

of a proper pervasion relation. A *contradictory* reason generates a conclusion which is opposite to what we want to establish. A *controversial* reason is one which is not able to clearly exhibit what it wants to show. The *counter-questioned* reason is a reason which does not state anything different from what is to be proved. The *mistimed* is a reason whose validity is past and thus is not relevant in the evaluation of a premise at a particular moment, even though it may have been so earlier.

In the Buddhist system, the structure of inference is dependent on the notion of valid or logical sign which obeys three conditions. Recollect that in Buddhist logic, the following three terms are important: locus, sign/reason and examples (both for similar and dissimilar cases). The possible fallacies are therefore those which are connected with these terms. Fallacies arising with respect to the locus (or thesis) are called *pakṣābhāsas*, with respect to reason are called *hetvābhāsas* and those concerning the similar and dissimilar cases are *dṛṣṭāntābhāsas.*[52]

Dignāga in his *Nyāya-pravesá* discusses the many kinds of fallacies that are possible with these three types of fallacies. The fallacies of locus/thesis are nine in kind, which includes fallacies that arise when a thesis is incompatible with perception, inference, one's doctrine, when it uses unfamiliar terms and so on.[53] As far as the reason is concerned, he identifies fourteen fallacies which indicate the kinds of wrong reasons in the context of a given thesis. These fourteen include reasons with these characteristics: *unproved* reason which is itself classified into four sub-divisions that includes reason which is not accepted by any party, when it is not accepted by one party and so on. Another fallacious reason is the *uncertain* reason which has six sub-divisions, such as reason which is too general, not general enough meaning that it is too specific as a consequence of which we may not be able to find similar and dissimilar cases, or that the reason is found to varying degrees in both similar and dissimilar cases and so on. The third major type of fallacious reason is the *contradictory*, which has four further sub-divisions. These arise

when the reason is in conflict with the thesis and inferred property.

These classifications point to what kinds of mistakes are possible in our inferential reasoning as far as the thesis and reason are concerned. It is also possible that mistakes can be made with respect to similar and dissimilar cases, specifically in identifying what exactly constitutes a proper example needed as part of the three conditions which reason has to satisfy. The fallacies with respect to the similar and dissimilar cases are classified separately and we are given five types of fallacies of the homogeneous (similar) example.[54] Similarly, there are five types of fallacies corresponding to the wrong use of the dissimilar or heterogeneous example.

The later Nyāya also classified many different types of fallacies. Like the early Nyāya, they too started with a primary classification of five types of fallacies such as unproved, uncertain and so on, but gave a much more detailed analysis of each one of these types. For example, Bhāsarvajña's description has twelve sub-kinds under unproved reason, eight under contradictory reason, seven for uncertain reason, six of the non-conclusive kind and six under mistimed reason. Further, he also adds two other types in addition to the five found in the *Nyāyasūtra*. As far as examples are concerned, there are six kinds of fallacies associated with similar examples and another six fallacies of dissimilar examples along with eight other kinds to do with both similar and dissimilar examples. Similarly, in the Navya-Nyāya tradition, we find five kinds of fallacies in the *Tattvacintāmaṇi*. We find similar classifications and concerns in the Jaina tradition also.

Why are fallacies so closely studied? In the Western tradition, fallacies are mistakes in the formal structure of the argument, meaning thereby that the argument from premises to conclusion is faulty independent of the status of the premises. Thus, a fallacious argument, for example, will be one which will generate a false conclusion even when the

premises are true. Other kinds of fallacious arguments include circular reasoning. In contrast, we find that the detailed classification of fallacies in the Indian traditions illustrates the many kinds of mistakes that can arise in a logical argument and are classified according to these different kinds of mistakes.

The importance given to pseudo-reason is also indicative of a particular view of reason. Firstly, the classification into various subtypes is most useful in debates when an opponent can be proven wrong by merely pointing out that the opponent's argument uses a reason which is fallacious as classified in a particular manner. It not only makes for effective debate but it also suggests that there is an objective standard and limited universal types of reason and fallacies of reason. I believe that it also suggests a constant awareness of how reason can go wrong. As much as 'getting it right', it is important to know *how* one can go wrong.

3.7.6 *Universal Positive and Negative Signs*

The triple condition for analysing sound inference was largely accepted by both the Buddhists and the Naiyāyikas. However, there were also some crucial differences between them, one of which was the Nyāya critique of Dignāga's wheel of reason. The triple condition demands examples of similar cases in which the valid sign is present *and* dissimilar cases in which it is absent. The later Naiyāyika, Uddyotakara, pointed out that this classification did not take into account those inferences in which the sign occurs in all cases so that there are no dissimilar cases. These signs, which have no dissimilar cases, are called universal positive signs.[55]

Let me clarify with an example. Consider the case of smoke and fire. In this example, we can find a dissimilar case, which is a lake. Now what if there is a property which is present everywhere, which therefore means that there is no location in which it cannot be present? Fire obviously is

not such a property. The traditional example to illustrate these special types of sign is this: 'This is nameable, because this is knowable.' For the Naiyāyikas, everything is nameable or expressible in language. Therefore, there can be no case where we could have something which is not nameable and therefore there can be no dissimilar case for this statement. Similarly, for the Buddhists, the statement that 'This is impermanent because it is a product' is a universal positive sign because in the Buddhist worldview there is nothing which is not impermanent. These two examples of universal positive sign are dependent on some philosophical position held by Buddhists and Naiyāyikas.

Similarly, universal negative signs are those that occur only in the subject locus. Just as the universal positive sign has no dissimilar case, the universal negative sign has no similar case. That is, there is only one subject locus in which the sign occurs. It is a unique occurrence. The question therefore is, if there is only a one-off unique occurrence and we are able to make an inference, then how do we analyse its validity? Uddyotakara classifies inference into three categories. One, the universally positive inference, where the inferred property is always present and there is no locus where the property is absent. Two, the universally negative inference, where the inferred property occurs only in one case, that is, there are no similar or dissimilar cases; and three, inference based on both positive and negative examples, that is, having both similar and dissimilar cases.

I believe that these unique types of signs are interesting because they are related to the idea of universal law and exemplify some idea of necessity. It is not an accident that the examples of this sign possess a lawlike character. Is the presence of this sign common to all lawlike statements? Matilal points out that for the Naiyāyikas the universal negative sign is important for it allows them to understand the nature of definitions whereas the Buddhists did not accept the validity of such signs.[56] For the Naiyāyikas, this sign was a definition of definition in a sense. Understanding definitions

is important because they play a crucial role in any philosophy and in science. I will discuss the Indian theories of definition in a section below and definition in Western context in the next chapter. The reason for doing this is to establish a philosophical framework that will allow us to understand the notion of scientific laws through the conceptual matrix of Indian philosophers.

3.7.7 *Definitions (lakṣaṇa)*

Definition is an important philosophical category, both in the Western and Indian traditions. Aristotle's understanding of definition was in terms of essence and further divisions into genus and differentia. There is very clearly the recognition that the role of definitions is not only to clarify what something is, but also to differentiate between two distinct things.

The emphasis on using definition to distinguish and differentiate one thing from another is fundamental to Indian approaches to definition. Another unique feature of their understanding of definition lies in relating it to inference and hence to sign or reason. In the Nyāya tradition, from early commentators such as Vātsyāyana to later Naiyāyikas, definition 'identifies a characteristic mark', which can help differentiate one thing from everything else.[57] The basic point in this approach is to understand how we can distinguish one thing from another, say a cow from a horse. We cannot just describe this difference in terms of properties because there are many properties that these two things may share. But it seems intuitively clear to us that while many properties may indeed be shared by these two creatures there is something special to each of them and that constitutes the differentiating mark. This mark could be a special real characteristic or it could be the appropriate universal. For example, the special distinguishing characteristic of a cow is the dewlap, seeing which we know the object can only be a cow. So, we can presumably define cow as that which has a dewlap. This type of definition is real in that it is based on some real

characteristic of the cow. There is another way to distinguish a cow and this is through the universal 'cowhood'. Therefore, we can define a cow as that which has 'cowhood', that characteristic which is present in all cows and which makes us recognise cows as cows. This is a nominal definition, a definition that is not based on some real property but on an abstract universal.

The Nyāya view relating definition to inference brings the problems of definition within the philosophical issues related to inference. First of all, when we use definition to make distinctions what we are doing is to make inferences of the type, 'If cow has dewlap (or cowhood), then it is distinct from all non-cows'. Matilal notes that given the definiendum (that which is defined) and definiens (that which does the defining) then the inference is of the form 'A is B, because C', where A is definiendum, B will be the inferred property and C is the sign/reason.[58] Relating definition to inference in this manner is a consequence of asking 'Why do we need definitions?' We need definitions because it helps us differentiate among things in the world but in doing so we make definition into inference. The moment definition becomes part of an inferential statement, we have to check whether it is a sound inference, that is, whether it satisfies the three conditions for valid inference. The Sanskrit word *lakṣaṇa* for definition, in common usage, means a mark, a sign, one which indicates a particular entity, *lakṣya.* We can see the language of inference already at use in the meaning of this word.

Matilal makes two points about definitions that will allow us to understand the larger relevance of the Indian, particularly Nyāya, view of it. First is that we can consider definitions as enabling one 'to correctly apply it to things or items it is supposed (or intended) to apply.'[59] Thus, as illustrated by the arguments given by Udayana, definitions have two purposes, one to differentiate and the other 'to warrant successful application of the expression "A" to the relevant objects.'[60] And second, he notes that the Greek

formulation of definition in terms of essence (and essential property) is different from the Nyāya formulation, where instead of *an* essence there is a set of unique defining properties.

What is the relationship between definition and knowledge? While accepting that definition does not create new knowledge, Udayana argues that it nevertheless has an important purpose. Matilal notes that for Udayana the purpose of definition in philosophy is similar to its use in medical or grammar texts. The similarity lies in that the 'medical texts give the defining character of particular diseases, and the text on grammar gives defining characters of correct usage of correct speech.'[61] Matilal's clarification of the above relation is worth summarising since it will serve to establish the connection between definitions in science and in Indian thought. A medical student, says Matilal, notes various characteristics in a patient and from the definitions given in the medical text identifies the disease, thereby learning to differentiate one disease from another. Therefore, even though a student of the medical text may be aware of the disease but not its characteristics so also philosophers can use definitions to understand the characteristics that define an object in a manner which differentiates it from other objects. Empirical information is thus an important part of definition. This should not be surprising given the overall strong empirical stance of Nyāya and also the analysis of definition in terms of inference, which demand similar and dissimilar cases as we have seen above. An important consequence of Nyāya's understanding of definition is that definition for them is not an 'analysis of the 'meaning' of the word, but rather with the application of the word to *things*.'[62]

We can now see why the theory of definition discussed here is not only relevant to philosophy but also to philosophy of science. I will only give some brief indications of this relevance here. Indian theories of definition are characterised by pragmatic concerns, characterised by the emphasis on applicational aspects of definition. The Nyāya approach of

taking definition into the fold of logic through inference is yet another unique character of their view on definition. Matilal notes one important consequence of the distinction between understanding definition in terms of essence or essential property (Aristotelian definition) and a set of unique, distinctive properties (Nyāya definition). Since picking out distinctive properties needs empirical input (and should also be empirically dynamic), definition as defined in this manner contributes to the growth of scientific knowledge. Moreover, following some contemporary discussions concerning distinctive properties, Matilal notes that the Nyāya theory of definition shares with these contemporary positions its commitment to a common core of realism about natural kinds and thus to a scientific worldview. In all this, we notice a striking overlap with definitions in science and in Nyāya. In the next chapter, I briefly describe some aspects of scientific definitions. From the summary of the Nyāya position given here, we can immediately see a close parallel between the Nyāya view and the operational mode of definition in science, and also the genetic definition which is commonly used in science.

3.7.8 *Properties*

In this final section, I will discuss a few pertinent ideas about the nature of property as described in Indian philosophy. Although this theme of property does not directly impinge on philosophy of science, it is nevertheless important since many of the ideas described in this chapter are based on some notion of property. There is also a very interesting formulation of absence in Indian philosophy, which, I believe, has deep significance to many contemporary philosophical issues, including in the area of philosophy of science. This section concludes with a brief discussion on the idea of absence.

How do Indian philosophies deal with the nature of property? Analysis of property is very important for certain

traditions such as analytical philosophy. The basic question about properties has to do with understanding how properties occur in particulars. In Western philosophy the standard approach to this issue describes the relation of properties to particulars in terms of an instantiation relation. Properties, such as colour, are not particulars in themselves, where by particulars we mean concrete things in the world. Particulars are distinct from each other and properties can be common to many particulars just as the colour red occurs in many red things such as a red house, red shoe and so on. This commonality of properties—their occurrence in many particulars—has been understood by viewing properties as universals. And some of the questions about universals are: what are they, do they have independent existence and how are they related to particulars? Properties are seen either as being Platonic, that is having an existence independent of the particulars or as being Aristotelian, where properties are defined through the particulars they reside in.

In Indian philosophy there are many interesting features in the description of properties. Some of the important logical problems also deal with properties. In inference, the logical sign is a property seeing which we infer another property. But in what sense are these properties? For example, in inference, the property which we see is smoke and we infer the property fire. Stating it thus is misleading. Fire is not a property per se. If we look carefully at the example, we see that properties belong to the subject-locus. So smoke, as well as fire, are properties of the *pakṣa,* the hill. Inference only relates a property belonging to a subject to another property which also belongs to the same subject. The inference of smoke and fire is not a general inference which says that where there is smoke there is fire. It specifies the inference and locates it in a subject. But the question still remains as to whether smoke or fire can be seen as properties of a hill.

The first point to note is the way in which properties are expressed in Indian philosophy. Typically, properties qualify

a subject. So a property such as blue qualifies a pot in the sense that the 'pot is blue-possessing' instead of the way we express it in English, which is that 'the pot is blue'. The usual way of expressing the smoke–fire case is by saying that the hill is fire-possessing and smoke-possessing. The problem with the idea of property, especially when seen in contrast to some contemporary accounts of it, is that the term property is used in a variety of contexts. Matilal notes that *dharma*, which is translated as property, refers not only to abstract properties such as colour but also to particulars, meaning even objects such as rock and so on.[63] For example, if there is a pen on the table it is conceivable to call the pen a property of the table as long as we understand it as implying the table is pen-possessing. For these reasons, Matilal suggests, at least for the problematical cases, the use of terms such as locatee, locatable and locus for talking about properties.

The Navya-Nyāya formulation of properties gives an insight into the worldview of properties, universals and particulars. The crucial themes in understanding properties seem to be location, relation of property to the locus, negation and negatability of terms meaning thereby phrases such as 'not-blue' and so on. Matilal's summary of the Navya-Nyāya theory of properties is as follows.[64] Properties are located and locatable in various loci. The universe is nothing but the collection of all the loci in which properties are found. Simple examples of property are sufficient to illustrate this view. A blue jar has the property blue located in the jar. The property of blueness is similarly 'located' in the colour blue. Note that the idea of location is not a specific physical location. Being located is like instantiation or the relation in Indian philosophy called inherence (*samavāya*), which is the relation between a property and its locus.

A property can be found in many locations and the 'presence-range' of a property is the set of all loci where it can be found. Similarly, the 'absence-range' is the set where the property is not found. For example, the property of

cowhood will only be found on the set of cows and will be absent everywhere else. An important point in Indian logic, as described earlier, is the insistence on using premises which do not have empty terms. This condition is equivalent to saying that the presence-range of properties has to be non-empty, meaning thereby that there is at least one case where a given property is to be found. This therefore precludes talk of any property which is not found in any loci.

Through this formulation, Navya-Nyāya describes what it means to be a fictional property.[65] The common examples of these include 'golden hill' and 'horned rabbit'. These fictional properties are defined to be those properties which have an empty presence-range, that is, there is no locus where they are to be found. Common properties like blue colour will be locatable in some loci and not locatable in others. Naiyāyikas also allow another kind of property which have an empty absence-range. This means that there is no location where the property is absent from, implying that it is present everywhere. These are also seen as non-fictitious properties and the common example is 'knowability'. This property is ever-present for Nyāya because of their belief that everything nameable (that is verbalisable) is knowable.

One of the most interesting descriptions in Nyāya is the negation of properties. Usually, given A, we say that the negation of A is not-A. Bivalent logic is based upon this dichotomy between A and its negation. In Nyāya, both absence and difference are types of negations. Negation is of a term and not of a sentence. Absence is a specific form of negation. In common talk, absence indicates that a property is not present, does not occur in a particular locus. Here the property in itself is a positive term, so there is no absence of the property but the absence of its occurrence in a particular location. For Nyāya, a property being absent in a particular location is seen to be equivalent to the occurrence of the absence of that property. Consider this example discussed by Matilal: 'The pot is not blue'.[66] The property blue is absent in the pot. How do we understand this absence? If

absence is a property then since properties are defined through occurrence in a location, then absence too should be defined through occurrence at a location. When we say that the pot does not have the colour blue we are noting its absence at a particular locus. Nyāya understands this statement as 'The pot *has* the absence of blue colour'.

The implication of this is that absences are seen as real and objective. The early Nyāya described three types of 'relational absence': absence of something before its production, that is, prior absence; absence through destruction; absolute absence, where one property is always absent with respect to a locus, say fire in a lake. Before an object, say a pot, comes into existence, it is absent. If we make a commitment to absence, like Nyāya does, then we will have to say that the absence of the pot before its creation is real in the sense that the absence occupied the locus where the material pot occupied after its creation. Similarly for the destruction of the pot: for after the pot is destructed what is left in that locus? Absence of the pot is what is left there.

The other kind of negation is that of identity. When two things are different from each other, there is a difference in some properties that defines these two things. When one thing x is different from another y, what exactly does this mean? We can say x is different from y because x has certain properties and y has some other properties and these properties are different. However, not all properties have to be different for one thing to be different from another. When we say that two things are necessarily different then perhaps we mean that there are some essential properties that are different in each of them. This difference is actually characterised by the statement that x does not have the essential property that y has, say y-ness. This, for the Nyāya, is equivalently stated as x has the absence of y-ness and this reality of the absence of y-ness is what allows us to say that x is distinct from y.

The importance of the language of absence is most forcefully seen in the analysis of pervasion, particularly in

Gaṅgeśa. In the section on pervasion we have seen a hint of how the idea of absence is deployed in the arguments for pervasion. The analysis of absence in Indian philosophy, like the many other themes we have encountered earlier, is not intellectually frozen or dated. There is something fundamental about these issues which can help us reflect upon contemporary philosophical problems with a new perspective. In particular, since these ideas share a great affinity with themes in science, we can see the potential use of these ideas in philosophy of science, thereby letting philosophy of science respond to the intellectual challenges posed by other non-Western philosophical traditions. Although I do not discuss Jaina logic here, it is another tradition which has suggested new ideas in understanding multi-valued logic and perspectives from different standpoints. I believe that ideas of Jaina logic are potentially useful in sociology of science and, in general, in discourses which attempt to find ways to express the plurality of objective worldviews.

4

LOGIC IN SCIENCE: THE WESTERN WAY

What is the relationship between science and logic? Among all human activities, science is seen to be the exemplar of logical thought and analysis. This is mainly because the methodology and the results of science are related to ideas such as objectivity, truth, laws, rationality and so on. Science is also explicitly connected with logic through its use of mathematics. In the development of modern logic, the association between mathematics and logic proved to be very important. On the one hand, the shift to symbolic logic meant that logic was being presented in a form similar to mathematics. On the other, the belief that mathematics can be entirely reduced to logic, meaning thereby that all mathematical statements can be reduced to logical statements, brought mathematics and logic much closer. This belief called logicism, championed so bravely by Russell, also depends on the belief that mathematics is the exemplar of deductive logic.

In the last chapter, we have discussed the argument that Greek logic was modelled on mathematics. Although mathematics in Greek times and in the times of Russell was vastly different, some basic beliefs about the nature of mathematics remained the same. Some of these continue to inform the image of mathematics. For example, mathematical truths, like 2 + 2 = 4, are considered to be universal truths. They do not depend upon individual human perspectives or on specific material conditions, including

dependence on space and time. They are understood to embody some fundamental, objective and universal structures, independent of the contingency of our existence. This also means that they are not empirically grounded, that is, their truths do not depend upon our observation, experiment or any other form of intervention in the world.

The relation of science with logic is also manifested in other ways. While the mathematical component of science is seen to reflect the deductive structure of argument in science, there is much in science which draws upon other forms of argumentation, particularly inductive inferences. Many of these inferences in science follow the same structure as the common inferences we make, such as the inference of fire from smoke. Thus, the philosophical issues that arise in analysing inferences in science share some common conceptual ground with 'ordinary' everyday inferences. Paradoxically, the strong empirical grounding of science places it in potential conflict with the Western tradition of logic. Science draws upon observations and reason, and using them together constructs its narrative of the world.

So how do we analyse the relationship between science and logic? I want to suggest two metaphoric images that capture two different ways of analysing this relation. One is along the lines which philosophy of science has done and done so admirably. This I call the *logic in science* view, which is the argument that philosophy of science draws upon Western logic with its baggage of philosophical ideas and tries to fit science to philosophy. Thus, this becomes a search for elements of logic in science. Equivalently, it can be understood as a demand for science to be logical. As a consequence, it is often felt that science is moulded to fit some concerns of logic and this sometimes leads to a belief among many scientists that philosophy of science not only often misunderstands science but also misrepresents it.[1]

However, there is another way of understanding this relation, which is well exemplified by Indian logic. I would like to characterise this approach as *science in logic*. As we

saw in the last chapter, many conceptual ideas that arise in Indian logic resonate strongly with scientific methodology and praxis. This does not in any way imply that Indian logic is 'doing' science. *What it is doing, however, is expecting logic itself to be scientific, in contrast with the position that science be logical.*

In this chapter, I will discuss how Western philosophical traditions have tried to understand the problem of inference, particularly induction, since this is a theme that they share with Indian logic, and how science has been looked at through the rubric of Western logic. This chapter can be seen as a brief introduction to some important topics in philosophy of science.

4.1 *Deduction in Science*

Scientists do not do science by asking whether their thoughts are 'logical'. In their practice and methodology, scientists indulge in activities which are many times habits and rituals. In fact, scientific knowledge, like other knowledge systems, has a strong ritual component to it.[2] Being ritualistic is also to be methodological and one of the important characteristics of methodology is that it trains one to do something without much reflection on what they are doing. Scientific methodology shares this trait with various other human activities which are ritualistic in character even as it is distinct from them in other important ways. To distinguish practice and method, philosophers of science have found it convenient to introduce two phrases. One is the 'context of discovery' and the other is the 'context of justification'. Habits, creative thinking, serendipity, 'irrational' action and such, are placed under the context of discovery. The step of justifying these discoveries and results, where the claims are placed within a larger community for acceptance, is a process that is apparently not arbitrary, illogical or irrational.[3] It is in this domain that logic makes an obvious entry.

Therefore, it is not surprising that the association of logic in science is primarily found in scientific methodology much

more than in everyday scientific practice. Much of science is based on ways of thinking which are quite similar to what we do in our ordinary lives. Scientists do not infer any differently from non-scientists, although they may subject their inferential conclusions to more rigorous and varied kinds of tests. What is different in scientific thinking is the domain of things they think about, the tools they use to analyse and an undercurrent of scepticism in their thinking combined with a strong streak of pragmatism. But as far as being logical is concerned, the ways in which they are logical share great similarity with the ways in which other humans are logical. This conclusion is almost tautological if we understand, as many do, that logic is about 'laws of human thought', which I suppose all humans must share if there are indeed such laws.

However, the methodological instinct in science takes commonsense logic to a more refined level. Thus, it is no surprise that the relation between logic and science is closely related to methodology. For example, Cohen and Nagel make explicit this connection by noting that in essence 'scientific method is simply the pursuit of truth as determined by logical considerations.'[4] A common element in this method is the process of hypothesis formation and it is no surprise that among the first elements of scientific methodology, the above authors mention the formulation of proper hypothesis. It is very possible that formulating a hypothesis to explain a phenomenon may well feature non-logical elements since sometimes hypotheses are mistakenly chosen. But, on the other hand, knowing how to frame an appropriate hypothesis is itself part of methodology. However, logic makes its proper appearance when deductive consequences of the hypothesis are explored. Thus, from some hypotheses we make on observing a phenomenon, we deduce possible consequences and if those consequences hold good then it suggests that the hypothesis is right. This, in essence, is the hypothetico-deductive model that has been discussed in great detail in philosophy of science.

Science, in a fundamental sense, can be understood as a discipline that constructs theories based on some observations and in so doing uses certain logical processes. Theories describe, explain and predict. Framing hypotheses and deductively arguing for their consequences are also an integral part of theory-making. In general, the explicit role of logic is first manifested in the move from some observation to a theory about this observation. Logic is also manifested in the various logical relations between theories and observations. Trusted gives a few types of logical implications in science.[5]

1. 'If the attraction between two masses is inversely proportional to the square of the distance between them, and there is a sun with one ambient planet, then the orbits of the planet will be an ellipse with the sun in one focus.' This is one of Kepler's laws and is an example of strict implication: it has an if-then structure and the phrase following 'then' is deduced from the antecedent, that is, the condition following 'if'. This statement can also be expressed in a counterfactual form and in structure will be similar to the reductio argument in Indian logic discussed under the heading of *tarka* in the last chapter.
2. 'If an animal has more than six legs then it is not an insect.' This implication follows from definition. We can see that this kind of inference is Dharmakīrti's first kind of inference, that is inference based on own-nature. We can also see the connection between these kinds of definitional statements and Nyāya's view of definitions described in the last chapter.
3. 'If a piece of litmus is placed in acid then it will turn pink.' This is an example of causal implication and is empirically grounded. One cannot make this statement by deduction alone but need experimental data to assert this. Note that this is Dharmakīrti's second kind of inference, inference based on causal relation.

4. 'If the phlogiston theory is true then I can fly out of the window.' This is material implication and is the weakest of the lot since the implication relation appears to relate two arbitrary phrases. Such inferences, which have no empirical basis, are obviously invalid in Indian logic.

The presence of such implications in science leads Trusted to argue that 'relation of theories and laws to each other and to observation statements may be compared to that of strict implication in deductive logic.'[6] We can see why it is important for some philosophers to argue that the relation between theories and observations is like logical implication. If the theory–observation relation is logical, then it allows us to claim that if the theory is true then the appropriate observation entailed by the theory must also be true. An important principle of implication is that in a conditional of the form 'If p, then q', when p is true, q has to be true. So if we look upon theory as p and observation statements as q, then if p is true it implies that q has to be true. Such a logical relation also satisfies the other condition, namely, that if observations are true it does not imply the appropriate theory is true, following from the logical consequence that if q is true, it is not necessary that p must also be true.

It would be an exaggeration to claim that scientists know the logical rule of implication when they construct theories or do experiments. It is not an accident that logic is not a course taught to scientists at any level nor is it required learning as part of scientific pedagogy! One possible reason for this is the belief that scientific methodology internalises logic and thus a student of science has only to learn how to do science and not worry about foundational issues. If so, it would be useful to see in what way science has internalised logic in its normal practice. Inductive inferences are very common, since they are most often extensions of our commonsensical inferences. The issue is how deductive logic gets internalised in the practice of science. One important way in which this is done is through the use of mathematics.

4.2 *Deduction and Mathematics*

In this section, I want to develop a critical response to the commonly held view that science exhibits a deductive structure, manifested largely in its use of mathematics. We have already seen the many similarities between logical and mathematical statements, which include their claim to independence from empirical concerns. Moreover, both logic and mathematics are suspicious of natural languages like English and they construct themselves by manipulating and modifying natural language. Both these points need to be critically analysed.

It is often remarked that the absorption of mathematics into science in the time of Galileo marks a transition to modern science. An array of great scientists over the ages from Galileo onwards held (and continue to hold) the view that nature is an open book written in the language of mathematics and the job of scientists is merely to read this book, implying thereby that to be a scientist it is necessary to be a mathematician. This influential view brings mathematics into the fold of science in an essential manner. In a way, this absorption of mathematics into modern science already allows logic to be an integral part of science. But just as much as there is more to mathematics than logic so also there is more to science than logic. All three are in a complex relation with each other, a relation which is problematised by the completely different impetus that drives each one of these activities. Science is immersed in the world in a way which mathematics and logic are not. Why then should mathematics and logic matter to science? One simple answer is that even in the ordinary experiences of our lives, we draw upon the world as well as use reason to make sense of our experience. Therefore, mathematics and logic are potentially as much 'useful' in our lives as in science. However, to say this is to misunderstand the special role that mathematics plays in the sciences, a role that is not given to formal logic.

The physicist, Eugene Wigner, popularised the phrase 'The unreasonable effectiveness of mathematics'.[7] He wrote about

the mysteriousness of the applicability of mathematics in the natural sciences. The mystery, not of mathematics per se, but of its use in the empirical sciences has led various eminent scientists to see this whole process as a mysterious one. Einstein wondered how it is "possible that mathematics, a product of human thought that is independent of experience, fits so excellently the objects of physical reality?"[8] The mysteriousness and the unreasonable effectiveness of mathematics only reflect the difficulty in appreciating both the independence, on the one hand, and necessity, on the other, of mathematics in the sciences.

However, there is one significant difference in the way science 'uses' mathematics in contrast to logic. First of all, what are the grounds for the belief that mathematics is essential to science? We can identify two reasons that are of relevance to this discussion. One is that the use of mathematics helps in unification, in expressing with great simplicity complex processes, allows economical explanation and so on. The other significant reason is that the use of mathematics makes possible predictions of new phenomena and new entities, thereby suggesting that mathematics has a special capacity to unravel the secrets of nature.

The question is whether logic also plays a similar role in science. That is, is logic unreasonably effective in the sciences? Does logic help science in making predictions or otherwise contribute essentially to the activity of science? By logic, I mean the discipline of ancient and modern Western logic and by its applicability I mean the use of the many logical concepts and techniques created by these logicians. I think it is reasonable at this point to note that the impact of logic on science is insignificant compared to the impact of mathematics. Science continues as it has all these years, ignoring developments in logic. But it is not so with mathematics. In fact, scientists routinely mine the playground of mathematics to discover new concepts, ideas and proofs. That they do not do the same with new developments in logic might suggest either their indifference to logic as is practiced

in modern logic or the ineffectiveness of logical concerns in the practice of science. If science is so closely aligned with logic as many would have it, then they will have to answer why science is so 'unreasonably indifferent' to it.

One might argue that science is itself based on basic logical processes such as deductive and inductive inference. Granting this basic inherence of some logical ideas, which are derivable either from the Western or Indian traditions, we can still argue that modern logic does not contribute to modern science in a way mathematics does. If one responds to this claim by saying that modern mathematics is the Trojan horse for modern logic, and that logic, therefore, enters into science through the use of mathematics, then they miss not only the complex relation between science and mathematics but also between mathematics and logic. The view that mathematics is not independent of the world is a view that needs to be seriously considered, if not for any reason other than for making sense of the mysterious applicability of it in the sciences. Logic constructs itself by creating an unbridgeable distance with the world. Mathematics, on the other hand, arises in various ways from our interaction with the world.[9] If we understand mathematics as arising from our experiences with the world, if we acknowledge that mathematics functions like a language in some essential sense, that it embodies ambiguity and sustains metaphoric imagination, then we can understand, however incompletely, its applicability in the sciences and also its alienation from logic, a logic which does not know how to deal with or incorporate the empirical within its concerns.[10] As long as logic keeps its distance from explicitly engaging with the empirical, its impact on the practice of science will continue to be negligible. And if there is anything unique about Indian logic, it is this constant engagement between the logical and the empirical.

Much of what I have said here refers to deductive logic. However, science is not possible without the extensive use of inductive inferences. The uncertainty in such inferences

creates a potential conflict for science and scientific methodology can be seen as a method of trying to make such inferences as certain as possible. In doing this, science is doing something similar to what the Indian logicians were doing in their attempts to define pervasion and to carefully define the notion of valid sign. We will now see how Western philosophical traditions handled this problem of induction.

4.3 *Induction*

We have briefly discussed induction in the previous chapter. Induction is a type of inference.[11] Consider some common examples: a ball that is thrown up in the air falls down. We see this happening many times and in many places, and we generalise from particular observations to the general claim that whenever a ball is thrown up, it will fall down. This capacity to describe a particular behaviour of the ball in all cases, whether spread over space (wherever) or time (whenever), is a mysterious one. What allows us to talk about these cases with any measure of certainty? We also make inductive inferences when we draw conclusions about all members of a class from some observed members. For example, from tasting one drop of sea water we conclude that all drops of sea water will be salty. Although in normal usage we tend to use the word 'all', such generalisations are also expressible through statistical generalisations, such as saying that something is true 60% of the time. Such examples are called induction by enumeration. Analogy is another kind of induction where from observation of some property or properties in one object we infer similar properties in other objects.

We can distinguish between deduction and induction in this manner: deduction is nonampliative inference and induction is ampliative inference. In ampliative inference the conclusion contains more than what is in the premises. For Hume, there was no possibility of deductive certainty for such ampliative inferences. Although induction by

enumeration, namely, inductively inferring the next case based on previous cases, is a common example of induction, Hume's problem holds for any ampliative inference, including general scientific laws.

One can respond to scepticism about inductive certainty by explaining how induction could be justified and describing some principles that can explain how induction is possible. When we make an inductive inference, we might have some reasons for making such an inference. But these principles might never be enough to justify induction. There is an underdetermination inherent in induction and this underdetermination can be expressed in different ways. Generally, an outcome is underdetermined means that 'some information about initial conditions and rules or principles does not guarantee a unique solution.'[12]

Justification of induction cannot depend on observation because induction by its very nature talks about the unobserved cases. We might then consider whether reason, theory, principles and other such terms can help account for our inductive capacity. But the use of principles and such does not really get us out of the problem easily since we first need to explain how these principles are themselves justified. For example, one can argue that the inductive generalisation that all objects when dropped will fall is a consequence of the law of gravity. But the law of gravity itself is dependent on observation; the day an observation goes against this law, the law will be jettisoned. So scientific principles or laws, which by their nature are dependent on empirical observations, cannot get us out of the problem. Perhaps mathematical formulations do but the problem in this case is that generalisations about world events and about mathematical entities or processes are quite different. Also, it is interesting to note that mathematical proof by induction is itself an important method of proof in mathematics.

There are two useful ways of approaching the nature of induction. One is to look for the means of justification and the other is to merely describe the process of induction.

What can justify induction? For Hume, induction suggests a hidden premise that nature is uniform. Thus, generalisation to the cases of unobserved is possible because we expect nature to continue to behave the way it did earlier. This explains why an event that happened earlier continues to happen in the same way later, why a pattern seen in some cases can be generalised to other unobserved cases and so on. But while this explains one aspect of induction there is still a justification needed for our belief that nature is uniform. However, even the claim that nature is uniform is also an inductive conclusion. So, justifying induction on the basis of uniformity of nature is not possible. This circularity is illustrative of various arguments that purport to solve these problems of induction.

Kant's rationalistic attempt, a non-empirical justification for induction, has been an influential contribution to this issue. Instead of reducing induction to the problem of predicting a behaviour or relation in observed and unobservable cases, Kant understands induction as a necessary way of understanding the world. Kant achieves this by introducing the ideas of analytic and synthetic statements and principles. Analytic statements are statements where the meaning of the subject contains that of the predicate. These statements do not need other factors to validate them and they cannot be contradictory in nature. A common example of an analytic statement is 'All bachelors are unmarried'. Synthetic statements on the other hand have an empirical or factual content. In such statements, the property predicated to the subject depends on some empirical information. A statement such as 'Apple is sweet' says something about the apple which is not necessarily true of the apple and cannot be known before tasting it.

Kant then distinguishes between analytic and synthetic *a priori* statements. Synthetic *a priori* statements not only say something more about the subject than is available in the definition of the subject but this more is not derived through observation and experience. Our reason alone has the

capacity to generate such complex, synthetic statements without drawing upon the world. And the best examples of such statements, for Kant, come from geometry and arithmetic, whose statements, he claims, are synthetic *a priori*. Kant's answer to the problem of induction arises from the possibility of synthetic *a priori* statements. Thus, statements of the form 'Every event has a cause', which is usually understood as an empirical statement or at least derived from our experience, would, for Kant, be given in our understanding as it were, without any connection to experience. It is independent of experience in the sense that we would believe in this statement irrespective of our own experiences. In fact, Kant argues that our experiences are already structured by our mind such that the observation that every event has a cause comes not from the world but from our understanding. The various categories of understanding actually shape how our experiences are structured.

It is well known that Kant was woken from his 'dogmatic slumbers' after he read Hume and we can see in Kant's philosophy a way of answering Hume's problems about induction. The question is whether our capacity to make inductive inference is part of the synthetic *a priori* principles. Kant answers this by responding to Hume's basic critique of induction, namely, the belief in the uniformity of nature. Salmon notes that Kant's formulation of causation as a synthetic *a priori* truth establishes the uniformity of nature.[13] That is, our experience will be so structured by reason that nature will always seem to be uniform, thereby giving us a reason to believe in the uniformity of nature which is itself not based on induction. Salmon also notes that Kant's formulation cannot answer properly to Hume both because such a principle of universal causation cannot be really established and because his view does not cover all causes and events, and does not provide ways to 'distinguish sound from unsound inductions'.

The approach to induction that is most commonly accepted today is the probabilistic approach. Probability captures an essence of induction, namely, that inductive conclusions can only be probable but being probable is not to be completely uncertain. However, the important question is whether we can define probability without a circular reference to induction. A popular approach to an understanding of probability is in terms of frequency; the greater the frequency of occurrence, the higher the probability of occurrence. Salmon argues that the frequency interpretation does not solve Hume's problem because the problem is that no inductive inference, if understood as frequency, can be justified. We can also understand probability as 'degree of rational belief'. In this view, probability is a means of rational justification for believing in a statement. But then how would we know what is rational justification? This is determined by evidence. The challenge then is to define evidence without taking recourse to induction, and this is a problem because many times it is not possible to know what evidence is without giving prior rules for defining what constitutes evidence.

However, there is an important consequence of this approach. It is that the problem of induction can be 'reformulated as a problem about evidence.'[14] Even if there are principles that underlie induction, evidence is needed to accept them as such. An added attraction of this view is that this approach of understanding probability along the trajectory of rational belief and evidence, brings the Western formulation of induction much closer to the Indian logicians' views on it. Dignāga's three conditions, as we have seen earlier, are primarily about evidence and what is needed for some observations to count as evidence for the inferential statement. To rephrase the Indian logicians' response, it would be that demanding examples from similar and dissimilar cases is the way towards a higher degree of rational belief in the inferential statement. These actually constitute criteria for what counts as evidence for a particular inference.

4.4 *Descriptive Models of Induction*

Given the difficulty in justifying induction, we can perhaps better understand induction by describing the process of induction in detail. Lipton notes that while one might think that this descriptive process should be relatively simple, nevertheless it is a 'shock to discover how extraordinarily difficult the problem of description has turned out to be.'[15] The capacity to think inductively does not mean that we can describe how we do it. The problem about description is also one similar to underdetermination: in describing induction, one always needs more to describe than what is available.

Nevertheless there are various descriptions that are available. For Hume, induction is part of habits. We see some recurring patterns or similar behaviours and based on them we make various kinds of inferences. We are then able to make an inductive jump because we have been inculcated in the habit of noticing these similarities and patterns. So, our capacity to generalise is in some sense a reflection of our propensity for habitual thought. However, there are various problems in this view. One is that we have many habits which we do not use to make inductive inferences. This means that we choose which habits we use to make such inferences. Why is this so? What is that makes us choose only some habits and not others? For example, I may see a particular table in a room every day of my life but still will not infer that it will be so forever. So, we have to understand why some habits lead to inference but others do not. Also, as Lipton notes, this view about habits will not explain how we infer unobservables, since we presumably do not observe unobservables.

Another descriptive model is called the instantial model. The basic idea in this model is that the support for an inductive statement comes from all the positive instances. A hypothesis that 'All A's are B' is supported by all positive, observed instances of A's which are B's. This may seem like a justification for induction but this model does not really

justify why the particular inference has been made. It only says that if we make an inference, then every time it is confirmed it is an added support that we have made the right inference. From repeated confirmation we can deduce that the next observed A will be B. However, the problem is that it is not clear what confirms an inductive inference and this poses a serious challenge to this model. Since the problem of confirmation has also been discussed in the context of Indian philosophy, it will be useful to briefly address this issue.

Let us consider the common example of an inference: 'All ravens are black'. It is clear that every black raven we see is a confirmation of this inference. Also, the first instance of a non-black raven will disconfirm this hypothesis. But there is an added complication, described by Hempel. The inference that all ravens are black is logically equivalent to its contrapositive, namely, all non-black things are non-ravens.[16] And what confirms this statement is the set of all non-black things which are also non-ravens, such as green leaves or red shoes. Each time we see a green leaf it is a support for the hypothesis that all non-black things are non-ravens, which logically implies that a green leaf is a support for the claim that all ravens are black. This seems problematical although it is not immediately obvious what exactly is the problem. We may disagree with the claim that if something confirms a statement it should also confirm its contrapositive. So, we could weaken the claim that logically equivalent statements have the same support or evidence, but this seems to be counterintuitive. Whatever be the case, the basic point is that confirmation through positive instances illustrates one kind of support for an inference but not for other kinds of inferences, such as inference of unobservables. It has been suggested by some authors that Dignāga's three conditions helps to address this problem in an effective manner.[17]

Another influential model which also gives a description of inductive support is the hypothetico–deductive model, which I discuss later in this chapter. There have been various other

attempts to find some foundational justification for induction. An influential model draws upon the idea of explanation and in particular on the relation between explanation and inference captured well by the now popular phrase, 'inference to the best explanation'. According to this view, what we infer offers the best explanation of the evidence, that is, 'explanatory considerations are our guide to inference.'[18] Given their importance in science and philosophy of science, the topics of explanation and inference to the best explanation will be discussed separately below. In the next chapter we will see how Indian logic shares a common conceptual space with these ideas.

Finally, let us consider two interesting formulations about induction, both of which have relevance not only to science but also to themes in Indian philosophy. One is by Reichenbach and the other is by Goodman. Reichenbach argues that if we are able to make generalisations which are found to be empirically true and also to generate true scientific laws through induction then inductive inference has to be valid. This is a variation of the pragmatist's argument, based as it is on some notion of use-value. Reichenbach's pragmatic argument (which must remind us of Peirce) offers a useful way of responding to the problem of induction. Reichenbach accepts that we cannot establish certainty of inductive inference but we can justify the methodology of generalisation by noting that it is the best system for prediction based on ampliative inference that we have and it works. As long as it works, it is justification enough to continue to use such inferences.

Goodman's approach is an entirely different way of dealing with the problem of induction. For Goodman, the problem about justification is not so much the justification of inductive inference as much as understanding how the particular inferences are generated. He draws upon the observation that even in the cases of deductive inference, rules of inference are justified if they generate valid inferences. If they do not, then the validity and rules of inference are both amenable to

appropriate changes. Deductive inferences are seen as valid if they conform with certain rules of inference which we think have some objective validity but 'we use them because they work'. So, Goodman is arguing that deductive inferences are also like inductive inferences in the sense that we accept only those deductive inferences as valid which have been tested for centuries. Similarly, even in inductive inference we need only to accept the fact that rules of inference can be changed depending on circumstances. Goodman argues, therefore, that justification is not an important issue for induction. Rather it is the question 'what *are* the valid principles of inductive inference?' For Hume, regularity gives rise to 'habits of expectation' but Goodman argues that only some regularities establish such habits and some do not. He goes on to say that 'predictions based on some regularities are valid while based on other regularities are not.'[19] Since the problem of justification of induction is closely aligned to that of confirmation, the question in the context of induction should therefore be: 'What is to be regarded as appropriate confirmation of a law, a generalisation or a theory?' In the previous chapter, I have already discussed some aspects of this confirmation problem in the context of Indian logic. Here, we need only note that the three conditions that are considered in Indian logic actually correspond to attempts to find valid principles of induction and they conceptually engage deeply with the notion of confirmation and disconfirmation.

4.5 *Mill's Methods*

There is another useful model to describe induction. This is the causal model, where inference is understood as a causal process. There are three reasons why I discuss this model separately. One, many inferences seem to be based on our awareness of a causal connection. Two, causal inferences have an important place in Indian logic. Three, science privileges causal explanations and inferences. Also, as

mentioned in the last chapter, Matilal suggests that Mill's methods to find the correct causal condition is similar to Dignāga's triple condition of signs. Thus, it will be useful to discuss Mill's methods in some detail.

As has been widely noted, we most often infer probable causes from the effects we observe. (In the last chapter, we saw many examples of inferences, based on causal relation, discussed by ancient Indian philosophers.) The inference we make from effect to cause is quite different from that of cause to effect. But how is it possible for us to infer from effect to cause? The problem is that it is difficult to isolate a particular cause for an effect since in general there will be many causal factors involved. Mill, attempting to answer Hume, justifies induction by law of universal causation—every event must have a cause—along with the law which states that like causes produce like effects. Mill proposed a simple but effective model to discover the correct causal relation although his methods have a fatal flaw as far as induction is concerned, since they are themselves dependent on induction. Mill described five methods which help isolate the true causal conditions from those that are irrelevant to a particular process. Mill understands cause as 'that condition which is the invariable and necessary antecedent of a phenomenon.'[20] The five methods are as follows.

1. The method of agreement: 'If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the phenomenon.'[21] This method is usually symbolically represented as follows. Suppose a, b, c and d are the conditions which are present when there is an effect x. This process can be represented as abcd → x. The method of agreement suggests that by changing the various conditions, we can identify the real cause of x. For example, suppose the factor d is changed to some other factor e. So what we have now is the set of conditions a, b, c and e. Now, in the

presence of these four factors if x still obtains, then we have eliminated d as the causal factor responsible for x. Symbolically, abce → x implies that d is not the causal factor. Similarly we can eliminate c by replacing c by f and if x still obtains, then c is not the cause. And so on. That is, if abdf → x, acdg → x and only a is common to all of these steps, then a is the cause of x. The problem with this method is the need for strict control which allows us to change b, c and d while still generating the effect x. Also, in all these cases, it should be possible to create the effect under various changing conditions. There is no inference made from the non-presence of some effect and thus this method consists only of positive instances.

2. The method of difference: 'If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ is the effect, or the cause, or an indispensable part of the cause, of the phenomenon.'[22] This method is enshrined in the modern ideas of experimentation, especially in what is often called as controlled experiments. Here, if the factors a, b, c and d are potential causal conditions for the effect x, then this method suggests that we can know for sure that a is the cause of x if not-a along with b, c, and d does not cause x. That is, by eliminating a, if we also find that x does not occur, then it shows that a is the cause of x. Unlike the first method, note that this method is about the absence of x and not the positive instances of x. Symbolically, if abcd → x and (not-a)bcd → not-x, then we can infer that a is the cause of x. This is also called induction by elimination.
3. The joint method of agreement and difference: 'If two or more instances in which the phenomenon occurs

have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance, the circumstance in which alone the two sets of instances differ is the effect, or the cause, or an indispensable part of the cause of the phenomenon.'[23] This method is quite commonly used in experiments such as finding appropriate medicines for various ailments. This method uses both the above methods and is the most important of these methods. It has often been remarked that this method best describes the scientific methodology for finding likely causes.

4. The method of concomitant variations: 'Whatever phenomenon varies in any manner, whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation.'[24] This method is also reflected not only in scientific method but also in many of our ordinary inferences. Here, rather than eliminating a condition completely, which might anyway be impossible in many cases, it is varied. Now, if the effect also varies as the condition is varied then we can infer that there is a connection between that particular condition and the effect. Note that it is possible in principle to eliminate one particular condition by continuously decreasing that particular condition.
5. The method of residues: 'Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.'[25] This is an important method in science. A common example to illustrate this case is the discovery of the planet Neptune. This planet was not directly observed but inferred from the presence of an irregularity in the motion of Uranus. This irregularity was not explainable if the existing

planets alone were taken into account. So the existence of Neptune was proposed as a hypothesis to explain these irregularities consistent with the belief that Neptune caused these irregularities.

The inferences that fall into these methods are causal ones. There are, of course, many generalisations and inferences that we make which are not causal. However, these methods give a useful way to discover what the relevant causal conditions are, since there are a large number of what we believe are causal inferences. Mill attempts to answer Hume's questions about induction and causation. Mill's theory of causation understands causation as not only invariable antecedence but also necessary antecedence. Further, cause, for Mill, is the total of all the positive and negative conditions taken together, a position that has echoes in the way science understands cause in terms of necessary and sufficient causes.[26]

However, like the other models, Mill's model too has some serious drawbacks. First of all, it cannot explain inferences that are not causal. Secondly, the methods described above are attempts to isolate single conditions, which is generally not possible. Also, it is not clear that it is possible to isolate conditions which are clearly distinct such as labelled by individual conditions a, b, c and d.

We can now analyse the validity of the claim that Mill's methods and Dignāga's conditions are similar. Consider the smoke–fire example. Fire is the cause and smoke is the effect. If we are looking at representing the inference in the form abcd → x, then x is smoke and let a be fire, b be mountain, c and d some other factors. The similarity condition changes b, because from a mountain we consider another location, a kitchen. If by changing b to e, we still have the effect, that is if aecd → x, then we can conclude that the mountain is not the cause for smoke (which should have been pretty obvious even without doing all this!).

It might therefore seem that the similarity condition of Dignāga duplicates Mill's method of agreement. However,

this would not be completely true. The similarity case is specific to the locus. The smoke in the mountain may have had many causes. The similarity condition does not explicitly eliminate each one of them like Mill's methods attempt to do. However, in finding another locus, it eliminates some of them at one stroke. For example, we could argue that one of the causal factors for smoke is the height of the hill. Mill's method would imply finding the effect when the height is changed. In Dignāga's case, the change of locus from mountain to the kitchen already eliminates the role of height. Thus, although certain factors are not explicitly eliminated in the similarity condition, we find that they are implicitly taken care of. Thus, Dignāga's conditions perhaps reflect an economy which is not present in Mill's methods.

Similarly, the dissimilarity condition is similar to the method of difference. A lake is the example of a dissimilar case because there is no factor of fire there. So what we are doing is asking whether (not-a)bcd → not-x. Since it is so, we can conclude that a is the causal factor that causes x. Thus, the triple condition defined by Dignāga is very similar, if not exactly equivalent, to Mill's joint method of agreement and difference.

Is there any significant difference? One difference, which is more clearly manifested in the dissimilar condition, is that we are not really searching for the correct causal factor, which is what Mill is doing. Dignāga's formulation seems more like a method of confirming a conclusion about a particular causal factor. That is, if I believe that fire causes smoke and I want to justify this belief, how do I go about doing it? Thus, we look for dissimilar cases where the cause is liable to be absent, like a lake for fire. It is not that Dignāga begins by noting that there is smoke, then lists a set of possible causal factors, and then uses the method of agreement and difference. Therefore, while the methods are very similar, the aims for doing it are slightly different. Of course, the aims match if a particular cause (or in general, a particular pervasion relation) does not obey the triple

conditions. In which case, we will begin the same analysis with another possible causal factor and by doing so we end up duplicating Mill's methods. Whatever be the case, it is clear that Dignāga's conditions predate by many centuries the most important of Mill's methods.

4.6 *Popper and the Problem of Induction*

Popper's contribution to the problem of induction is useful as much for his attempts to save science from the clutch of inductive reason as for the lessons we learn of the difficulties one faces in resolving this problem. Also, his formulation of falsification has been influential, especially among practicing scientists. Popper begins by attempting to understand what differentiates scientific disciplines from others such as psychology and history. Influenced by the precise predictions made by the theory of relativity, Popper argued that the mark of a scientific theory does not lie in obtaining confirmation but in attempts to falsify or refute it. The resistance of a theory to falsification indicates the scientific status of it; greater the resistance, the less scientific it is. The emphasis on falsification, as against verification, has many important implications. Popper believed that the ideas of falsification and related concepts were sufficient to solve the problem of induction. He revived the hypothetico-deductive (HD) model and used it to describe the methodology of science, primarily as a method of conjecture and refutation.

This model was revived and modified by Popper in response to the problem of induction in science. Popper was responding to the charge that scientific knowledge cannot be based on any certainty if it is dependent on induction. One way to defuse this charge is to claim that induction per se does not generate knowledge about the empirical world. Inductive inferences are nothing more than hypothesis, which are only tentative propositions with a possibility of being true. Given these propositions, we can logically deduce the consequences if they were true.

The underlying question is, given a hypothesis, what supports it? In the confirmation model, any positive instance of the hypothesis confirms it. In the HD model, the hypothesis, along with other auxiliary statements, leads to some predictions. The move from the main hypothesis and auxiliary ones to a prediction is a deductive inference, which, for example, can be achieved through mathematical calculations based on the hypothesis. Thus, the consequences of a hypothesis can be given in terms of some observations. If the observations match the prediction based on the hypothesis, then the hypothesis is correct. A well-known example of this process is the shape of planetary orbit. Kepler began with the hypothesis that the orbit of the planets is circular. With this hypothesis and using Tycho Brahe's observations, he calculated the position of Mars. This calculation did not match with the observation and therefore he inferred that the original hypothesis was wrong. He replaced the hypothesis of the circular orbit with a hypothesis of elliptical orbit, which was confirmed because of the match with his observations.[27]

Popper made an important distinction between confirmation and falsification. Instead of demanding confirmation of a hypothesis, Popper argued that we should find ways to falsify it. Once we frame a hypothesis, which we think best fits the facts, then we deduce the consequences of this hypothesis. These consequences must be testable and what we test for is not confirmation of these consequences but their falsification. If we are able to falsify the results then we have good reason to believe that the hypothesis is false. The essential point here is that we do not test for the confirmation of the consequence because confirmation does not necessarily imply that the main hypothesis is true. Confirmation, even repeated confirmations, cannot justify the hypothesis. This methodology of falsification is itself based on the logical structure of *modus tollens*: 'If p implies q and q is false, then p is also false'. Therefore, if a hypothesis (p) implies a consequence (q) and this consequence is found to

be false then logically the hypothesis is false. In the case of confirmation, we would have the structure: 'If p implies q and q is true, then p is true'. This conclusion is a logical fallacy called the fallacy of affirming the consequent. Thus, falsification has a logical basis which confirmation does not.

Although the argument for falsification is logically sound, Popper's model does not do the work he wants it to for the simple reason that there is no one-to-one link between consequence and hypothesis but only to consequence and a set of hypotheses, which will include the main hypothesis. Thus, as Duhem pointed out, we can never falsify a hypothesis because it may be the case that some of the auxiliary hypotheses may actually be the ones that are wrong. Further, introducing ad hoc hypothesis, including those which are incompatible with the original one, we can always save the original hypothesis. In spite of attempting to solve Hume's problem, Popper's method is itself dependent on induction at various points. And although the idea of falsification was further refined with the help of new concepts such as corroboration, verisimilitude and so on, his attempt to define the criterion of scientificity through falsification did not fully succeed.

At first glance, Popper's demand that a hypothesis should be falsified rather than confirmed might seem to be very similar to the triple condition of Indian logicians. Recall that Dignāga's triple condition demands that for a valid inference, the reason for making that inference should obey some conditions. One of them is that there should be similar cases. Similar cases confirm the hypothesis; for example, the similar case of kitchen confirms the hypothesis that where there is smoke, there is fire. Another condition is that there be no dissimilar cases. Is this condition similar to the falsification of the hypothesis?

On the surface, the third condition is not strictly like falsification. In the HD model, starting from a hypothesis we deduce the consequences. The falsification is with respect

to these consequences. For this to be possible the consequence derivable from the hypothesis must be of such a form that it can be falsified. This is possible if these consequences exhibit a rich empirical content, that is, make claims that can easily be shown to be false rather than shown to be right. Consider the hypothesis: where there is smoke, there is fire. How can this hypothesis be falsified? Firstly, note that this hypothesis by itself cannot be falsified but can only shown to be true or false. To be falsified, we need to deduce some consequences of the hypothesis. In this sense, the third condition is also a kind of confirmation. It is a confirmation of the statement, If no-fire, then no-smoke, since that is what this condition demands. Thus, the third condition does not exhibit the structure that arises in falsification. Also, note that falsification draws naturally on the idea of counterfactuals: if a particular hypothesis, then these would be the consequences.

However, it would be wrong to say that Indian logicians did not formulate ideas similar to falsification, although as far as I am aware there is no term in their system equivalent to Popper's falsification. To find this common link, we have to look to Dharmakīrti and his third type of inference, namely, inference from non-perception. Consider one of his eleven kinds of inference from non-perception. The fourth kind is given by this example: 'There is no cold touch here because there is fire here' (see Chapter 3). This statement is actually about the consequence of a fire that is at a particular place. Consider the hypothesis, 'there is fire here'. This is a hypothesis because we do not perceive the fire and it is being inferred from the fact that it is not cold here. We infer the presence of fire at a particular place not because we see smoke but because we know that the place is not cold. The argument for this conclusion is that if fire is present at a particular location, then one of the consequences will be that the location will not be cold. So, from detection of warmth we can infer fire. One could ask, why was not this inference written as, 'There is fire here because there is warmth here'?

But this is exactly the point about inference from non-perception. Popper's falsification criterion fits positive statements such as 'There is fire here because there is warmth here' since this is a consequence of fire which can easily be proved to be false. For Dharmakīrti, the consequence is not expressed positively by saying there is warmth but negatively by saying 'there is no cold touch here'. However, this consequence is open to falsification in the same way as the positive claim.

The above discussion is an attempt to expand the interpretative space of Indian logic by exploring what its boundaries are through the act of stretching and fitting other ideas and concepts. This discussion on Dharmakīrti and falsification is an exercise to find the elasticity possessed by certain philosophical concepts in the Indian tradition. And the success of this exercise is to be measured not by checking whether Dharmakīrti and Popper meant the same thing but whether they can both be seen as sharing some common conceptual space.

4.7 *Explanation*

We have looked at how science differs from other activities and disciplines. We began with logic and went on to consider how science deals with induction, its methodology as described by the hypothetico–deductive and the idea of falsification. There is yet another theme which sets science apart and that is the nature of its explanations.

We offer explanations in a variety of cases, ranging from phenomena in the natural world to personal relationships. The kinds of explanations that we offer vary as does our belief in the appropriateness of these explanations. There has been a sustained attempt to use different types of explanations to demarcate disciplines. For example, explanations in science have a unique character and philosophy of science has attempted to clarify the nature of scientific explanation. Unfortunately, this is not an easy task

as we will see below. In this section, I will be interested in exploring the relation between explanation and inference, and their relation with science. This introductory material on explanation will help us to establish the links between Indian logic and scientific explanation in the next chapter.

What does an explanation accomplish? Lipton suggests that explanation is an answer to the question 'What has to be added to knowledge to get understanding?' The analysis of explanation exhibits many of the same problems as that of induction, including the problems that arise in describing and justifying explanations. I begin by summarising some of the different accounts of explanation.[28]

Reason model: What does it mean to explain something? Many times when we are asked to explain why something happened we look for reasons that will describe why it happened the way it did. In the reason model approach, one understands what explanation is by finding reasons that will help us believe in the occurrence of the phenomenon. Lipton gives the example of an engineer's explanation of the collapse of a bridge using theories of stress etc., showing the collapse was likely. In contrast, if we have no reason to understand why a phenomenon occurred, we would tend to call that occurrence accidental or arbitrary. At first sight, the reason model seems to fit many explanations we make. As Lipton notes, this model 'suggests a natural connection between the explanatory and predictive uses of scientific theories since, in both cases, the theory works by providing grounds for belief.'[29] However, he considers this model to be extremely implausible for many reasons. Firstly, it does not differentiate between 'knowing that a phenomenon occurs and understanding why it occurs.' If a particular phenomenon has already occurred and we know that it has, then what role does reason have in explaining that phenomenon? Further, explanations may not be called for since we may already have a reason. Moreover, there are many explanations which do not actually give reason for the occurrence of a phenomenon, yet we accept them as doing the job of explaining.

Familiarity model: This model argues that unfamiliar phenomena need explanation and 'good explanations make them familiar.'[30] Being familiar means that there are some phenomena that are perhaps self-explanatory or do not call for an explanation. This process of making familiar is like reduction of explanation of unfamiliar phenomena to familiar ones. For example, the explanation of various aspects of heat by the kinetic theory of gases is based on a model that sees molecules as behaving like tiny billiard balls. But, in what sense are aspects of heat more unfamiliar than billiard balls? In this model, it is not clear whether familiarity or unfamiliarity refers to the phenomenon or the explanation for it. In the example of heat, the phenomena associated with heat are very familiar, perhaps more familiar than our experience with billiard balls but the explanation may be unfamiliar once we draw upon atomic physics. Also, this model does not explain why some explanations are familiar in the first place or why we often explain even familiar phenomena.

Deductive–nomological (DN) model: This is a well-known account of explanation. Somewhat like the hypothetico–deductive model, here too explanation is reduced to deduction from a set of premises. At least one of these premises is a natural law or generalisation. This model is similar to the reason model since premises act as reasons. The presence of laws is a strong requirement. One of the strengths of this model was that it claimed to correctly describe scientific explanations, although later theories disproved this claim. This model satisfies the initial idea of explanation in that it differentiates between knowing a phenomenon and understanding it (with the help of laws). However, there are serious problems with this model as a general theory of explanation. Firstly, it is too strong. Even for scientific explanations, as Lipton points out, the requirement of a law as a premise is too strong since many phenomena can be explained without taking recourse to such laws. Moreover, in many cases such laws cannot be found. This model is also

too weak—since it does not account for the asymmetries of explanation. That is, the use of the law does not distinguish between the explanans (that which explains) and the explanadum (that which is explained). In examples such as the explanation of red shift by Doppler effect, the same law can be used to deduce shift from recession as well as the recession from the shift. Like the hypothetico–deductive model, this model too is over-permissive and 'makes it far too easy to explain.'[31]

Causal model of explanation: The overlap between induction and explanation is found in the causal model of explanation. In this model, to explain a phenomenon 'is simply to give information about its causal history.'[32] If we want to explain the phenomenon of causal regularity itself, then to explain is to 'give information about the mechanism linking cause and effect.' There are obvious strengths in this model, including its avoidance of many problems which afflict the previous models. It helps us distinguish between understanding why and knowing that it is so, and thereby clarifies the nature of understanding as something related to the causal mechanism. In comparison with the DN model, there is no necessity to discover a law that will play a part in the explanation; although we should remember that causal links many times suggest laws or lawlike structures. However, if we thought that it was difficult to find laws then it is equally difficult to find the causal history, especially since causation is itself a difficult philosophical problem.

There are some difficult problems with this model also. First of all, the model as such does not describe clearly cause or causation. Secondly, there are many examples of non-causal explanations such as in mathematics, philosophy and even of some processes in the world. The third problem is that it is too weak—causal histories are 'long and wide' and 'most causal information does not provide a good explanation.'[33] Lipton argues that the Big Bang is part of every causal history but is irrelevant in most explanations. This is so with many such links in a causal history since most of the information in this history is irrelevant. But this

does not mean that causal histories do not explain. In making a causal explanation, we choose the relevant links. Following Hempel's observation that 'we do not explain events, only aspects of events,'[34] Lipton suggests that what we choose in the causal history depends on the specific issues that arise in what we want to explain. Thus, we do not explain the eclipse as such but only its longevity, partial nature and so on. Rarely are we asked for explanation as such but only explanation of some aspects and which aspect we explain depends on our interest and this choice will reduce the number of causes that figure in the causal history.

Lipton makes an important distinction between merely explaining and contrastive explanation. He argues that what is important in explanation is contrastive analysis. That is, we do not question 'why this', instead, we ask 'why this *rather than* that?'[35] This form of questioning focuses attention on specific aspects instead of attempting an overarching explanation. Contrasts provide the context for explanation. Lipton argues that contrastive questions are 'extremely natural' and while an *account* of a general explanation may be difficult, account of contrastive explanation is not necessarily so, even though explaining a contrast may be more difficult than explaining a plain fact.

How does a contrastive question supply an adequate answer? The point here is that it may be easier to answer a question of the form 'Why p rather than q?' instead of 'Why p?' alone. Why is this so? Lipton draws upon Mill's method of difference to understand the importance of contrastive questions. He finds a striking similarity between the method of difference and contrastive explanation although this method is an attempt to discover the appropriate causes and not give explanations. So he proposes that

> [F]or the causal explanation of events, explanatory contrasts select causes by means of what I will call the 'Difference Condition'. *To explain why P rather than Q, we must cite a causal difference between P and not-Q, consisting of a cause of P and the absence of a corresponding event in the history of not-Q.*[36] (italics in original)

In the second chapter, I discussed the Nyāya theory of doubt and argued that the notion of contrastive doubt was very important in their formulation. Earlier in this chapter, we have seen the overlap between Mill's methods and Indian logic. With the theory of contrastive explanation, which also draws upon Mill's methods, we find the possibility of bringing themes in Indian logic into the contemporary discussions on explanation, particularly scientific explanation. In the next chapter, this relation will be developed in more detail.

4.8 *Inference to the Best Explanation*

We have seen that there are striking similarities between induction and explanation. There are various themes that occur in both: the problem of justification, description, prediction, causation and so on. It might therefore not be a surprise to find an important relation between them that is manifested as the 'inference to the best explanation' (IBE). Why do we explain? Some of the models discussed above indicate how we might go about doing the job of explaining but do not address the issue of why we explain. Perhaps one way of understanding this question is to explain the act of explaining. While a general answer to this question may be extremely difficult, we can look at some specific types of situations where we can understand why some explanations are generated. There is an equivalent problem in the context of induction and inference. Why do we infer what we infer? After all, one can make many different possible inferences. For example, when we see smoke, why is it that we infer that there is fire? Why not a whole range of other possibilities? An analysis of inference, which does not somehow factor the reasons for the occurrence of a particular inference, might miss understanding something essential about inference. This problem is partly dealt with by the model of IBE.

Inference to the best explanation suggests that we infer what is the best explanation for a hypothesis. For example, when we see smoke, we infer that there is fire. Why do we

infer this? Because we think that the presence of fire is the explanation that best fits our perception of smoke. So our inference is primarily an inference to an explanation; one which best explains the phenomenon that we perceive. What we are essentially doing is to generate explanations to understand why a particular phenomenon is occurring. Among the many possible explanations, we infer the best one. Thus, Lipton writes, 'our choice of why-questions is often governed by our inferential interests, so that we choose contrasts that help us to determine which of competing explanatory hypotheses is correct.'[37] It is useful to list the examples given by Lipton in support of the commonality of this kind of inference. As examples of IBE, he gives the following: sleuth inferring that the butler committed a particular crime, as it is the best explanation of the evidence; a doctor inferring that a patient has measles as it is the best explanation of the symptoms; an astronomer inferring the existence of Neptune from the observed perturbations of Uranus since it is the best explanation and so on.[38] For Lipton, IBE suggests a 'new model of induction, one that binds explanation and inference in an intimate and exciting way' and emphasises how 'our inferential practices are governed by explanatory considerations.'[39]

However, there is an ambiguity about IBE which we should consider. Some writers describe IBE as one that basically chooses a best hypothesis, given many hypotheses that explain a phenomenon. This process has been called abduction, a term used by the American philosopher C. S. Peirce. In abduction, the end product of an inference is the hypothesis, instead of beginning with a hypothesis as in other modes of inference. In this view, an explanation is a hypothesis and inference to the best hypothesis is actually inference to the best explanation. This manner of presenting IBE is somewhat weaker than Lipton's version. For Lipton, there is a commitment to inferential and explanatory realism, namely the view that inferences and explanations have a role in

taking us towards truth. This necessitates acceptance of possible and not just actual explanations. It also leads Lipton into various other kinds of problems, including defining what would be the best explanation and so on. Since they do not immediately bear on the nature of explanation per se, I will ignore these issues here.

IBE's greatest strength is that it brings inference and explanation together. There are also other advantages of this model and also its share of disadvantages. Some of the advantages of this model are as follows: IBE itself explains our inferential practices; in explaining how we come to our inference it says something about discovery; it also explains why particular hypothesis are chosen; it helps to argue for scientific realism because 'it is the best explanation of predictive progress'; given its subjunctive element, namely, the possibility of answering the question ''how good the explanation *would* be if it were true,'[40] it helps us to know what kind of experiments we could perform; unlike the hypothetico–deductive method which starts with a given hypothesis and deduces consequences from it, IBE does not neglect how such hypotheses are created; and finally, it is a good argument for the 'truth' of science itself since this is the best explanation we can infer, given the success of science.

Among its problems, we can list the following. IBE cannot be a general model of explanation, since there are inferences which are not explanations. The idea of choosing the 'best' is a loaded problem, since the criteria of best should not be circularly based on the process of inferring and it is not clear that we can do so. Another criticism levelled at IBE is that it is nothing more than 'inference to the likeliest cause' and thereby relates explanation and inference to causation alone. Fraassen's two critiques of IBE are also telling. One is the argument from indifference. It is based on the problem of fitting a theory to a set of observations. As is well known, there can be more than one theory that can fit a set of data and some of these theories can be incompatible with

the kinds of entities they posit. Fraassen's argument is about the truth of the best explanation. Suppose we have the class of theories which can explain the data. Choosing the best among this set does not mean that we have chosen the true one since it is not necessary that the true theory must belong to this set. The second argument of Fraassen is that not only is it not necessary that the true theory belong to the class of empirically equivalent theories, it is also possible that all the explanations that we have are all false, in which case choosing the best one among these false theories still will not get us closer to a true theory.[41]

4.9 *Scientific Explanation*

We have discussed various approaches towards a general theory of explanation. But these models of explanation were about general explanations, whether they occur in our daily lives or in specialised activities like science. In trying to give one general formulation of explanations across such diverse domains, the philosophers are trying to do too much and it is not a surprise that there are various limitations in these models. In this section, I want to move away from considering explanation in general to explanation in science. Scientific explanations have a unique character although formulating this uniqueness is often difficult.

Science explains a wide variety of phenomena and entities. It tries to explain why the sky is blue and why objects move. It explains the origin of species and why some molecules react in particular ways. It explains the structure of the nucleus of the atom and also the symmetries of the universe, as well as the shape of a snail or the patterns of a number sequence. Are there common elements to all these explanations? Can we detect the essential nature of scientific explanation from all the explanations that science gives?

In order to explain an observed fact, we use various premises and arguments. What is to be explained is called the explanandum, and what does the explaining is called the

explanans. It is obvious that the structure of explanans and explanandum is not unique to science. But what would be unique to scientific explanation is the relation between these two, as well as the statements that are considered as the explanans. For one influential model, explanans in scientific explanation are unique in that at least one of them is a law. The presence of a law seems to add weight to an explanation. The association of a law with some notion of truth thus adds a sense of truth to explanation, and allows us to talk in terms of correct and wrong explanations.

This is the view of the DN model described earlier. This model enshrines the belief that laws contribute something essential to scientific explanation. Championed by Hempel, this model has also been called the covering-law model. Hempel's version is a useful illustration of the strengths and weaknesses of this account. The strength of this model derives from its deductive argument from premises, one of which at least is a law. The presence of a law along with deductive inference adds a measure of certainty to scientific explanations. The structure of the DN model can be given in the following manner.

> The explanation must be a valid deductive argument.
> The *explanans* must contain at least one general law actually needed in the deduction.
> The *explanans* must be empirically testable.
> The sentences in the *explanans* must be true.[42]

An important point to note here is that these conditions allow one to predict as well as explain an already observed fact. Thus, this model is symmetrical between prediction and explanation. If we look at the structure of the above formulation of scientific explanation, we immediately see the following features. First is the requirement of deductive argument. The insistence on deductive argument has been understood as guaranteeing the connection between the explanans and the explanandum. For it could be the case that we could have laws in the explanans but what is to

guarantee that the argument based on these laws will be related to the fact that needs explaining? Since the validity of deductive argument necessarily connects the premises and conclusion it seems reasonable to expect a deductive argument. However, there is an important difference and this has to do with the fact that the explanation is of scientific facts, which are necessarily empirical, and thus the logical structure should not only be valid but also be sound.

Among the sentences that do the explaining there must be at least one general law. There are two points to be noted here. One is the reference to 'general law' and the other the condition that the law must actually be used in the deductive argument. (Hempel's conception of a law included natural generalisations.) The second condition is required because one can construct arguments in which a law is present but is not used in deducing the conclusion. What makes this structure special to science is the third requirement that the explanans be empirically testable, a requirement that is essential to scientific formulation in general. But incorporating testability within a deductive structure is potentially problematical—this is exactly the problem that Indian logic supposedly runs into.

An example of the DN model illustrates the features of this model. If we want to explain why a Bunsen flame turned yellow at a particular moment, we could argue as follows.

> All Bunsen flames turn yellow when sodium compounds are placed in them.
> All rock salt consists of a sodium compound.
> A piece of rock salt was placed in this Bunsen flame at a particular time.
> - - - - -
> This Bunsen flame turned yellow at that time.[43]

This explanation, a scientific one, is a deduction with premises, which contain a natural law, as in the first two statements. The third statement is the initial condition needed for this explanation; it is the empirical content in the explanatory structure. The conclusion follows necessarily

given the three premises. However, this structure does not explain facts which are probabilistic or statistical. An attempt to introduce probability into the DN model changes the deductive structure. Statistical explanations are inductive and the inductive-statistical (IS) model of explanation reflects this character. In this case, the occurrence of the explanandum is given in terms of expectation or probability. In the case of IS, although a statistical law is used in the premises, the argument is inductive and not deductive.

There is also a second type of statistical explanation and it is called the deductive–statistical (DS) model. Like in the IS model, here also there is an attempt to explain statistical facts but the explanation is through deduction from statistical laws. Explanation of generalities is also an important part of scientific explanation. While facts are explained by both DN and IS models, general regularities are also explained by the DN and DS models. The crucial distinction is between the universal laws and statistical laws. The three models of explanation discussed above describe *all* scientific explanation. Salmon calls this the received view.[44]

However, the problem with this description is that not all scientific explanations fit into this logical structure. Note that all these models attempt to show that scientific explanations are either deductive or inductive arguments. Many counterexamples were generated to show how the restriction to purely logical analysis of explanation was wrong. These examples include the explanation of the shadow of a flagpole, a barometer reading mistakenly understood as explaining the storm and Salmon's example of a male who takes birth control pills thus explaining why he did not get pregnant. These counterexamples question the belief that scientific explanation could be entirely described in terms of formal, logical framework. Moreover, it was clear that science did not present its explanations as described in the received view. Even Hempel was aware that explanation in scientific discourse was dependent on various other factors. These factors were grouped together and called as

'pragmatic factors'. Following this, scientific explanation was understood to be a combination of logical and pragmatic factors. As Rosenberg suggests, it may be that models such as the DN model 'provides the distinctive features of *scientific* explanation, while the pragmatic element provides the features common to scientific and non-scientific *explanations.*'[45]

Following Salmon, it will be useful to summarise the different ways of understanding scientific explanation.[46] He notes three different views: epistemic, modal and ontic. Epistemic view, exemplified by the inferential version, understands scientific explanation to be arguments as in the models discussed above. The modal view relates scientific explanation to ideas of necessity in that explanations show that 'what did happen had to happen'. The problem for this view arises from indeterminism, particularly manifested in quantum mechanics. Also, this view explains universal or statistical regularities and does not consider explanations of individual events and facts. Although it might seem that explanation of generality would be more important for science, explanations of individual events and facts are also essential. This is especially the case when the explanation of these individual facts is actually used to construct a more general theory. The ontic view describes explanations in terms of causal links associated with natural patterns or regularities. The major problem in this view is the confusion about what constitutes causality and causation.

In the development of theories of scientific explanation, two distinct paths can be seen. One, following Hempel, understands scientific explanation as being a deductive or inductive argument, thereby subsuming the explanandum into natural laws. The other route consisted in identifying causality and explanation, thereby defining explanation as that which identifies the cause of an event. Thus, in this view, to explain a particular effect is to point to its cause. Friedman's attempt to understand explanation as unifying diverse phenomena suggests that explanation has an important unifying role. In

large part, the two approaches that have dominated contemporary analysis of scientific explanations are the unification model and the causal model.

The problem with the causal approach is basically the ambiguity about causality, especially the identification of the appropriate causal factors. As is well known, if an effect is caused by some condition, it is always in the background of many other factors which either help or obstruct the final effect. This problem can be partly dealt with by identifying causal conditions, namely, sufficient and necessary conditions. Following Salmon, another way of understanding causation is in terms of causal production and causal processes. The other way is to try and replace talk of causality with that of laws. However, this approach also does not take us too far given that unexceptional laws are indeed as difficult to handle as causal relations.

The unification model has many positive features and is closer to a scientist's understanding of scientific explanation. It also captures an ideal image of science where the value of science lies in its capacity to describe and explain a range of phenomena with very few principles. In this view, the power of explanation increases as the number of principles that do the explaining decreases.

The category of explanation has been much analysed in Western philosophy and in philosophy of science. Explanations are also an integral part of scientific activity. This introduction to some of the basic ideas in the philosophy of explanation is to set the stage for considering whether the unique structure of Indian logic illustrates concerns of explanation and not just inference. I will discuss this possibility in detail in the next chapter.

4.10 *Definitions*

Yet another important aspect of scientific activity is forming appropriate definitions. We have already seen in Chapter 3 the Indian approaches to definition. Definitions are essential

to any theoretical activity. They play a variety of roles, as attested by their various meanings. Definitions are also of great importance in science. In the Western tradition, there is a long history of various philosophers engaging with the idea of definition. Like explanans and explanandum in the context of explanation, we have the definiens (dfn) and definiendum (dfd) for definition. Definiendum is that which is described and definiens is that which is used to describe the definiendum. There is no more to the definiendum over and beyond that given by the definiens.

First of all, definitions are an attempt to remove ambiguity in our normal use of language. We use words to talk about things, concepts, processes and so on. Consider the example of an object. We use language to describe various aspects of the object. To define what this object is, is to do something little more formal. There are different ways of defining something. One is ostensive definition, pointing to an object that is to be defined. An ostensive definition of a cow can be given merely by pointing to it. A cow can also be described by its many properties. One can then say that I use the word 'cow' as an abbreviation for the collection of all its properties. This is called a nominal definition. This is very common in science since a long description of some idea, such as energy or entropy,[47] can be expressed by a word or an abbreviation which stands for it, and this word is chosen through convention. In contrast to this, we have what are called real definitions, where we define a word by analysing the 'idea' or 'form' behind the word. In this case, there is a belief that both dfn and dfd refer to some common property or entity like the 'idea' of wisdom, which is different from the word wisdom. In general, the equivalence of dfn and dfd or the translatability and substitutability between dfn and dfd are indicators of a definition.

Definitions are used for a range of entities such as things like cows or electrons, concepts such as wisdom or force and so on. Definition, we often believe, captures something essential about these terms, a view held by both Aristotle

and Plato. For Aristotle, the idea of definition was most important for his theory of science. He understood definition as signifying the essence of that which is defined. Essence is that which is the necessary and sufficient characteristic of a thing or concept. For example, if we ask what is it that makes a circle unique, we can answer by describing it as a figure such that any point on it is at the same distance from the centre.[18] This can be seen as its essence or equivalently, its definition. For Plato and Aristotle, definitions are real definitions, in the sense that they refer not just to words but to a thing. Aristotle views definition as having two components, genus and differentia. Genus identifies that which is common among different things, that is the shared characteristics of their individual essences. Thus, 'plane figure' is the genus for different entities such as circle, triangle and so on. These entities which fall under one genus are called species. Although they are grouped under one genus they are also different, a difference which is attested by their essence. That part of the essence which identifies this difference among each other, even though they are all a part of the same genus, is called differentia. Although there are many problems with a strict account of these terms, they nevertheless have been very influential and are widespread in definitions in science (and mathematics).

Other than understanding definitions as 'revealing the essence' of the thing to be defined, a position not only held by Aristotle but also by Hegel, there are also other meanings for definition. For example, definition as a means of 'explicating the content of concepts (Wolff, Kant)', 'establishing and clarifying the meaning of terms already used in language (Hobbes, Pascal)' and 'establishing the meaning of newly introduced terms and signs in the language of scientific theory.'[49] Definitions play a fundamental role in scientific activity. This is not surprising since the idea of definition itself arose in the need to clarify the use of language and to describe some essential elements of a thing or concept. One can actually have some rules for definitions, which will

help in the construction of definitions. For example, some of the rules for a definition are that it should give the essence of that which is defined, should not be circular (it should not use what it wants to define in the definition), not be described in negative terms (in terms of not-this and not-that) and should not use metaphoric language.[50] We can see from this description that definitions embody many characteristics that science demands of its descriptions.

Therefore, it should be no surprise that almost all terms, concepts and entities are defined in science. For example, Poincare argues that Newton's second law, $F = ma$, is circular since we do not know what mass and force are. He concludes that it 'is *by definition* that force is equal to the product of the mass and the acceleration.'[51] He also notes that Newton's third law is also only a definition. Mathematics is very much dependent on definitions. In many cases, these definitions are not given or known immediately. Sometimes, definitions change and get rectified.

Given the pragmatic nature of science, it should not surprise us to note that scientific definitions embody a pragmatic mode. This kind of definition in science is called operational definition, a term coined by Bridgman. Such definitions are: '(1) definitions of physical magnitudes through indication of a set of operations by which is measured (defined) some physical magnitude; (2) definitions of some properties of objects by a series of activities on them, in order to ascertain whether or not we have to do in this case with such a property.'[52] An example of the first type is Einstein's definitions of simultaneity and length, and of the second type the definition of acid as a 'liquid which turns litmus paper red'. We can immediately note the problem in defining acid in terms of its action on litmus paper. Acid acts in different ways with different substances and therefore the problem would be to specify which of these many properties should be used to define the acid. The operational definition is contextual in the sense that these definitions are not given completely. Instead, we need to define concepts

only operationally and it is in this sense that I invoked the idea of pragmatic and contextual dependency of definitions.

Operational definitions are extremely useful in science, mainly because it allows introducing a whole range of concepts and other abstractions without worrying whether the 'correct' definition has been given. The example of mass is a very good example of this since the definition of mass has changed over the centuries, each time changing according to some theories.[53] Since our definitions are answerable only in an operational sense we can proceed with doing science instead of getting into debates about whether the essence of the idea, like mass, has been captured in a particular definition. But this strength is also its weakness as far as the idea of definition (not restricted to scientific definition) is concerned. The weakness is that there is no unique equivalence between dfn and dfd; instead what we have is that for one definiendum there is a set of definiens. A circle can be defined in different ways as also an acid. However, the spirit of 'essence' is captured in the fact that even though there are many definiens there is still only one definiendum.

Some other types of definitions such as descriptive definitions are also used in science. I will only mention another type briefly since it is relevant to the larger concerns of this book. This is called the genetic definition, which is 'where the distinction of the object defined is achieved by reference to the way it was formed, generated, constructed, etc.'[54] This is a mode of definition that is common to many facets of our life. What this definition does is to give criterion for distinction based on aspects such as origin of the object or fact. We distinguish food, for example, by calling an item 'baked food' and another as 'fried food' and in so doing we are using genetic definitions. This type of definition covers a wide range of definitions in science, mathematics, medicines and so on.

In the previous chapter, I offered a brief description of definition in Indian philosophy. There is much in common in

the attempts to understand definition in both Indian and Western philosophies. In particular, the scientific approach to definition, informed as always by its pragmatism and empiricism, is strongly reflected in the Nyāya theory of definition. There are many issues that can be uncovered and analysed in this comparative study of definition, especially in the intersection of definitions in science and in Nyāya. I can only hope that I have shown reasonable evidence for motivating such an activity.

4.11 *Laws and Counterfactuals*

Science has a plethora of laws. It has different kinds of laws such as fundamental laws, phenomenological laws, dynamical laws and so on. Laws are the holy grail of science and the search for laws has been an important driving force for scientists. The image of nature as an open book written in mathematics, voiced so influentially by Galileo and others, was specifically about natural laws. There are many reasons as to why the idea of natural laws is so seductive to the scientific imagination. Laws have great explanatory power; with one law we can understand and explain an enormous number of divergent phenomena. Laws also capture the objective spirit that is essential to science. They embody universality and the ability to transcend particular individual events. Furthermore, laws reflect the order of the universe, an order without which scientific activity and discourse would not have been possible.[55] Finally, more than just being an idea, many laws have been discovered in science.

The philosophical literature on the nature of a law is very vast. Here, I want to consider laws mainly in the context of counterfactuals and generalities, because in Indian logic we have discussed the concept of pervasion and its lawlike nature. I believe that we can see the attempts by Indian logicians to frame issues similar to the concerns of Western philosophers about the nature of laws. Since laws are also fundamental to science, the relevance of this comparative discussion is immediately obvious in the context of this book.

It is ironic then that for a notion which is so much valued in science, there are still fundamental philosophical problems in our understanding of laws. Some of these problems have to do with the problem of causality, a problem briefly discussed earlier in this chapter. Others have to do with what we want a law to do. For example, the universality of laws has been criticised on the grounds that they are always given only in a context. Even fundamental laws, according to Cartwright, come with ceterius paribus conditions, that is, other-things-being-equal conditions, and therefore cannot be universal or fundamental.[56] Fraassen has forcefully claimed that there are no such entities as laws since they are nothing more than generalities.[57]

These claims about the nature of laws are not new. The basic source of the problem lies in the difficulty in distinguishing between accidental generalities and lawlike generalities. Both kinds of generalities are expressed in a similar manner, yet there seems to be something special that laws express as compared to statements of accidental generalities. A common example to illustrate this is as follows.

> All solid spherical masses of pure plutonium weigh less than 100,000 kilograms.
> All solid spherical masses of pure gold weigh less than 100,000 kilograms.[58]

Both these statements are similar yet there is a fundamental difference between them. The first statement about plutonium is necessarily true because it is in the nature of plutonium that we cannot have a solid sphere of plutonium above a critical mass. This is explained by radioactivity. The second statement is empirically true or at least expected to be empirically true, say because of the lack of that much gold in the universe. But this is not necessarily true, unlike the example of plutonium. The first statement is a consequence of a law whereas the second is not. How can we distinguish between such statements?

Philosophers have used the idea of counterfactuals to distinguish between accidental generalities and necessary

generalities.[59] We have come across counterfactuals in the section on *tarka* in the second chapter. A counterfactual is a conditional statement: it is an if-then statement but with a subjunctive (use of 'would') clause. Now, there is an argument that counterfactuals can help distinguish laws from accidental generalisations. Consider the example given above about the platinum and gold spheres. We can write the corresponding counterfactuals of these statements in the following manner.

> If it were the case that the moon is made of pure plutonium, it would be the case that it weighs less than 100,000 kilograms.
> If it were the case that the moon is made of pure gold, it would be the case that it weighs less than 100,000 kilograms.[60]

These counterfactuals are not about facts of the world. The very structure of these statements suggest that they are saying something about possible situations and not actual situations. Phrased in this manner, it seems that the statement about plutonium is capturing a truth which the statement about gold is not. It is not just that all plutonium spheres are less than a particular weight (because this could be just an accident) but that it is not possible for such a sphere of plutonium to exist. Now, when we claim that it is not possible for plutonium to exist in this manner, then we have to have a reason and this reason is the law. Thus, a law is used to support an appropriate counterfactual, whereas similar support is not available for accidental generalisations.

While the use of counterfactuals serves to indicate which generalisation could be a law it does not explain why something should be related in a particular manner. For example, in the plutonium example the law of radioactivity supports the counterfactual of the plutonium sphere. There is no such law that can support the counterfactual claim relating to the gold sphere. But why is it that laws do this? What is it in the nature of laws that they support counterfactuals?

In trying to understand this issue, we come back once again to the notion of causality. In the plutonium case, we

can say that the radioactivity of plutonium causes particular kinds of reactions which become uncontrollable when some small critical mass of plutonium is present. Science uses the language of causes extensively in talking about laws, although this should be taken to mean that there indeed are clearly defined causal relations. However, as we have seen earlier, invoking causes is only to push the problems into a different basket. Since my aim is to bring philosophical themes from Indian philosophy to reflect upon science, I will restrict myself to the brief comments on laws made above, especially the relation between laws, counterfactuals and causality.

There is yet another formulation of laws which shares common ground with Indian philosophy. This is the understanding of a law as a relation between two universals. The lawlike statement that 'All As are Bs' is said to be a relation between two universals corresponding to A and B. This formulation has been quite popular, especially in contemporary analytical philosophy.[61] The language of relation and universals brings the discussion of laws much closer to Indian philosophy because one of the essential ideas about generalities discussed in Indian logic understands them as being relations of universals. In the Indian tradition, the pervasion relation (discussed separately in a section in the last chapter) comes closest to being a *scientific law.* Note that a counterfactual, for example, of the smoke–fire inference, is supported by the awareness of the pervasion relation, which thus functions like a law. The attempt to define pervasion in the complex manner described in the last chapter clearly exhibits their attempts to capture the essence of a law through the use of counterfactuals, absences, universals and related concepts.

In this chapter, I have summarised some important themes in the philosophy of science. The choice of these themes is based on their potential overlap with similar themes in Indian logic and philosophy. Since I see this book as an introductory one, I have separately discussed themes in Indian logic in Chapter 3 and philosophy of science here, so that before

comparative philosophy is attempted, there is some clarity on the formulations of these ideas in different philosophical traditions. However, I have also indicated at various points in both these chapters how this comparison, and thus a potential dialogue, could be established between the traditions of Indian philosophy, Western philosophy and modern science. The next chapter will engage in a much more interactive comparison between all these three traditions.

5

SCIENCE IN LOGIC: THE INDIAN WAY?

What commonality can there be between logical systems developed over a millennia ago and the activity of modern science? Is it a case of attempting to stretch ideas and concepts beyond their respective domains of applicability? The previous chapter argued that some aspects of Indian philosophy are very relevant to the philosophy of science. This relevance will be explored in a more sustained manner in this chapter. Here, I explore some not so standard themes, derived from Indian philosophy, that are relevant to philosophy of science, thereby expanding the vocabulary and the universe of discourse both of Indian philosophy and philosophy of science. Thus, I have emphasised semiotics, analysis of the symbolic domain found in logic and mathematics, the relation between signs and theories, theory–experiment link, models of explanation and their relation to the nature of Indian logic. The image I would like to work with in this chapter is the image of science in logic. As mentioned in the last chapter, I believe that Indian logic is usefully understood as demanding that logic should be scientific, in contrast to the standard way in which science has been understood in the Western tradition that science be logical. In this sense, Indian logic exemplifies scientific methodology at its core.

5.1 *Indian Logic and Science: Trying too Hard to Fit?*

How can ancient and medieval Indian logic, and philosophy in general, matter to an understanding of modern science?

Is this attempt to find such relevance ideological or intellectual? These are questions that are often asked when the subject of Indian philosophy is raised in the context of contemporary thought.

These questions are easily answered. Philosophy of science is first and foremost philosophy. Contemporary philosophy of science has seen fit to primarily draw upon ancient, medieval and modern philosophical traditions from the West. The influence of philosophers like Aristotle and Plato is obvious in philosophy of science and in contemporary philosophy as well. The relevance of 'old' philosophies to philosophy of science only suggests that some of the basic philosophical questions, which are necessary to understand the nature of science, continue to make sense in today's context. So, if ancient Western philosophy can be so important to philosophy of science, then it should not be a surprise that Indian philosophy could also be similarly relevant.

This observation is strengthened by the fact that some of the philosophical themes in Greek thought are also the ones that have been critically analysed by Indian philosophers. Moreover, as I have been arguing all along, Indian logic shows a 'natural' connection with scientific method, unlike the Greek tradition, especially its logic. In this chapter, we will explore this connection in various ways.

How can the analysis of examples from Indian logic matter to science today? For example, what can we learn from the over-used example of smoke and fire in Indian logic (like the Socrates-mortal example in Greek logic) that can be of any use to understanding modern science? There is much in science that looks complex but some old questions remain at its foundations. For example, how do we move from observations to talking about observations? How can we distinguish between accidental generalisations and necessary relations? What is the role of language in describing the world? How can observations confirm a generalisation? What does it mean to verify a hypothesis? And so on. These questions are not necessarily answered by science and

philosophical insights are often needed. Indian logicians and philosophers deal with very similar questions. Moreover, Indian logicians developed their logic based on principles that today we would call empirical and scientific. Hence one would expect greater similarity between Indian logic and philosophy of science.

Moreover, if we look at any scientific theory, we will see that some of what is done there is similar to what the Indian and Greek logicians were doing. Let me briefly consider Newton's laws in order to illustrate this. Newton's three laws are more like hypotheses. They are not deductively derived from other principles. The second law states that 'The change of motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.'[1] In current notation this is written as 'Force = mass × acceleration' or 'F = ma' (ignoring the vector character of the force and acceleration). One way of looking at this statement is this: 'Where there is acceleration, there is force'. Science is filled with such inferential moves. For example: If symmetry, then conservation of some physical quantity like charge. If lightning, then electrical discharge. Seeing an unknown liquid react violently when mixed with water, we infer the liquid is an acid and so on. Even more complex conclusions, as in many theoretical results, are composed of many inferential statements like the above. How does science judge which of these statements are valid? In theoretical physics, for example, mathematical derivations and proofs supply validity in many cases. However, this does not mean that mathematics generates these inferences; it may only offer a 'proof' of our inferences. For example, the statement 'If symmetry, then conservation' can be proved mathematically for some kinds of symmetry. However, the result itself is a generalisation of some earlier observations. While I do not want to reduce the extremely rich and complex discourse of science into a set of inferential statements, it must also be kept in mind that, especially at the foundational level, science is not devoid of such statements.

Consider this statement. 'Where there is change of speed, there is force' or equivalently, 'Where there is acceleration, there is force'. It is useful to compare it with the smoke–fire inference, 'Where there is smoke, there is fire'. Note that the reverse inference 'Where there is fire, there is smoke' which is false, also has an equivalent statement 'Where there is force, there is acceleration', which is also false, since we can have many forces that cancel out each other and therefore there will be no net acceleration. So, the proper inference seems to be 'Where there is acceleration, there is force'. In this sense, Newton's law is an inferential statement of the above kind.

First of all, would we be correct in rewriting the second law in the above manner? Newton defines force as the cause of acceleration. As far as force is the cause of acceleration, the statement of the law is very much like the statement that arises from the recognition that fire causes smoke. Just as we infer the presence of fire from seeing smoke, so too should we infer the presence of force on 'seeing' acceleration. If force is the cause and acceleration is the effect, then we need evidence for this causal relation. Why would we say that force causes acceleration? What makes Newton come to this conclusion? Saying that it is a definition only leads us into further problems. If this statement is a scientific one, then it should be based on empirical observations. If it is based on empirical observations, then it is reasonable to believe that it is like a generalisation based on many such observations. Poincare argues that F = ma is circular since we do not know what mass and force are. He says, '[it] is *by definition* that force is equal to the product of the mass and the acceleration' and further that 'this is a principle which is henceforth beyond the reach of any future experiment.'[2]

Jammer notes that force was not being defined in the second law of motion, although it has been so interpreted by some. He suggests that there are two possible interpretations of the second law: 'it may serve as a quantitative definition of force or as a generalisation of empirical facts.'[3] He rejects

the possibility that this law is a definition of force, since Newton clearly distinguished between definitions and axioms. The concept of force, for Newton, was not only intuitive but was derived from 'analogy to muscular force,' suggesting once more that scientific concepts many times are based on simple inferential analogies and patterns. In fact, the study of impact of bodies was already a well-developed field with important inputs from Galileo, among others. The idea of force and its relation with mass and velocity was suggested by more than one writer before Newton. This relation was part of the study of impact of bodies and therefore was empirically founded. However, Jammer does not hold the possibility that the law itself is an inference from the 'laws of impact'; rather its creation was a 'stroke of genius'. It should also be noted that Newton was able to make a shift from the physical mooring of the idea of force into an abstract mathematical notion.

Whichever way we understand Newton's law, the basic point is that it establishes a relation between different concepts. The examples of Indian logic, to reiterate, are not restricted to material signs such as smoke. As we saw earlier, examples in Indian logic deal with relations between concepts like knowability and nameabililty or producthood and non-eternality. Just as the Indian philosophers developed concepts such as these, scientists develop concepts such as force, mass and acceleration. While there are different methods to understand the relation between concepts, the basic concern of the Indian logicians (as well as scientists) was to analyse the validity of these relations as well as the measure of certainty about them, based on evidence and reason. If we consider Newton's law as relating force and acceleration, then the question is how can we be certain about this relation. Dignāga would argue that acceleration is a valid sign for the presence of force if this sign satisfies the three conditions for valid sign/reason. This implies that the sign should satisfy the similarity and dissimilarity conditions. Later in this chapter we will see how these conditions of Dignāga share methodological similarities with science.

Having said this, I want to note two essential differences, both of which help us understand where scientific reasoning parts ways with Indian logical reasoning. Firstly, in science concepts are open to rectification based on observations.[4] Concepts in science are used to define and create other concepts and thus concepts are in a dynamic universe of their own. Using logical analysis to *develop* new concepts seems to be lacking in Indian logic, especially when compared to science. Secondly, the establishment of these relations in science is catalysed by their potential use in different contexts. The establishment of Newton's law is not just a theoretical exercise but is actually used to describe hundreds of situations. Thus, laws and generalisations in science are seen as part of a larger theoretical framework, whereas, for Indian logic, the analysis of these arguments is the last stage and the proper conclusion is reached once we are sure of the correctness of the inference. For example, in the examples of Indian logic, the task of the logician seems to end when the analysis of the relation between eternality and producthood of sound is analysed. The next step, which science would have made, is to use the valid relations in order to build something else on them, a move which Indian logic does not seem to explicitly make.

5.2 *Logic as Semiotic: Peirce on Signs*

The use of the idea of sign should alert us to the semiotic character of Indian logic although the emphasis on inference tends to overshadow this important character. It is interesting that Matilal in the appendix of his book *The Word and the World* has a short essay on the semiotic conception in Indian logic, all of which is part of the material in his *Character of Logic in India.* Unfortunately, he does not expand further on the possible semiotic interpretation of Indian logic. The semiotic interpretation of Indian logic is not only useful but also indicates the essential aspect of this logic. The following sections will explore this relation in greater detail. In this

section, I will discuss the relation between logic and semiotics, largely drawing upon Peirce.

The word sign is derived from *signum*, originally *sēmēion*, which was often a synonym of *tekmērion*, and was used to mean proof, clue and symptom.[5] These meanings share a common semantic space with the ideas of sign, reason and evidence, which are, as we have seen earlier, used in various ways in Indian logic. In the Western tradition, the Stoics had the 'first and most thorough sign theory ever produced' and among the examples of inference, the smoke–fire inference was the 'most elementary type of recollectable sign.'[6] Eco notes that the Stoic model of sign is an inferential model of p implying q, 'where the variables are neither physical realities nor events, but the propositions that express the events. A column of smoke is not a sign unless the interpreter sees the event as the true antecedent of a hypothetical reasoning (*if* there is smoke...) which is related by inference (more or less necessary) to its consequent (...*then* there is fire).[7] The sign is not the material sign of a particular column of smoke but is a type standing for smoke. In comparison with Indian logic, we might say that this is a sign removed twice, since the type smoke stands for a particular column of smoke which is the sign for fire (as in Indian logic). Furthermore, the inferences studied by the Stoics were not concerned with the epistemological relation between the terms in the inference, although Aristotle distinguished between necessary and weak signs based on epistemological concerns. Inference is a logical argument and the relation between signs and logic already appears here. However, there is a deeper engagement with logic and sign, one that needs to be explored before we understand the possible interpretations and extensions of Indian logic, especially in the context of science.

Charles Sanders Peirce was an important American philosopher. His most seminal contributions were in the areas of semiotics, logic, pragmatism and scientific method. In many of his ideas, he shares an uncanny resemblance with

Indian philosophers. In the second chapter, I have already discussed his views on doubt which are similar to the Nyāya view. I introduce a few of his ideas here in order to expand the dialogical space in which to place the relevance of Indian philosophy in the context of philosophy of science.

I begin with what Peirce writes about logic. 'Logic, in its general sense is ... only another name for *semiotic* (...), the quasi-necessary, or formal, doctrine of signs.' By this he means that 'we observe the characters of such signs as we know, and from such an observation, by a process which I will not object to naming Abstraction, we are led to statements, eminently fallible, and therefore in one sense by no means necessary, as to what *must be* the characters of all signs used by a "scientific" intelligence, that is to say, by an intelligence capable of learning by experience.'[8]

Peirce begins by defining sign, in a way similar to Dignāga, as 'something which stands to somebody or something in some respect or capacity.' There are three elements to a sign: the creation of another sign in the mind, the sign standing for an object, and the presence of an idea in reference to which the sign stands for the object. The second element of the sign, namely its capacity to stand for some other object, is what Peirce calls logic. Thus, 'logic proper is the formal science of the conditions of the truth of representations.'[9]

There are three types of sign for Peirce, what he calls three trichotomies. The first trichotomy consists of signs which is a 'mere quality, actual existent, or is a general law'. The second trichotomy includes signs based on their relation to the object and the third has 'sign of fact' or sign of reason. Each of these types has different kinds of signs within them. In the first trichotomy there are three kinds of signs: qualisign, sinsign and a legisign. A qualisign is a quality which functions as a sign to denote another thing—for example, the quality of red denoting a colour red. Our experience of red is not of the red colour or red thing in itself but is a sign pointing to the red object or red colour. A sinsign is an actual thing or

event that occurs only once and acts as a sign. A legisign is a law which functions as a sign. Conventions are included under laws and Peirce gives the example of the usage of 'the' as having the same meaning as an example.

The better known classification of signs by Peirce are the three types of sign under the second trichotomy. These three types are called the icon, index and symbol. An icon is a sign that resembles an object, like a picture of a tree which has some semblance of similarity with the tree. An index is a sign that is a sign for an object which affects it and thus is modified by the object. A symbol is a sign that is accepted by convention as referring to an object. An icon indicates the object it refers to and the example given by Peirce is a lead-pencil streak which is seen as referring to a geometrical line. It is an icon because the line shares some characteristics with the straight line and thus indicates that it stands for such a geometric line. An icon has no physical or 'dynamic' connection with the object it stands for and the similarity which it has with the object is not due to any 'connection' with that object. It is the similarities that make us think that the sign functions as an icon.

An index is an objective sign and would not have been there if not for the object. If the object were removed then the sign would be present (that is why it is objective) but would not have the same meaning. The example he gives is a 'piece of mould with a bullet-hole in it as a sign of a shot'. The hole is the sign, index, which is pointing to a bullet having been fired into the mould and if there had been no shot, there would have been no hole. Peirce notes three distinguishing marks of an indexical sign: 'first, that they have no significant resemblance to their objects; second, that they refer to individuals, single units, single collections of units, or single continua; third, that they direct the attention to their objects by blind compulsion.'[10] Further, he says that indices depend upon 'association by contiguity' and not through resemblance. Some examples given by Peirce include clock (as the index) indicating time of day, rap on the door,

a low barometer with moist air is an index of rain, weathercock an index of the direction of wind, pole star an index showing the direction north and words such as 'that' and 'this'.

The symbol can be best understood as being entirely conventional and interpretative, and hence if there is no subject who interprets then there is no symbol. Thus, for Peirce, the symbol 'is connected with its object by virtue of the idea of the symbol-using mind, without which no such connection would exist.'[11] Further, a symbol is not related to a particular object; instead, it 'denotes a kind of thing' such as the word 'star' which stands for a set of objects.

The third trichotomy also has three signs called rheme, dicisign and dicent sign. A rheme is a sign of qualitative possibility, meaning thereby that it can represent a possible object. A dicent sign is a sign of actual existence. A dicent sign or an argument is a sign of law. What we see here is a taxonomy of different types of signs. In the Peircean view, signs are encompassing and include linguistic markers also as signs. For Peirce, logic would involve knowing correctly which sign stands for what and the nature of that standing-for.

Peirce has a further classification of ten classes of signs but I will not discuss them here. I mention this only to make the observation that yet another characteristic which Peirce shared with Indian philosophers was this tendency to create taxonomies!

It is also worthwhile noting that Peirce's analysis of signs necessarily incorporates the role of the experiencing subject, since it is the subject who interprets the sign. Those who call Indian logic a psychologistic enterprise would do well to study Peirce who, working within this structure of object, sign and interpretation, is still able to distinguish subjective reasoning and an objective, logical method.

Buchler in his introduction to Peirce's work notes that Peirce's path-breaking contribution is his 'conception of logic as the philosophy of communication, or theory of signs.'[12]

He also says that the 'conception of logic as semiotic opens broad, new possibilities.' Arguably, we can well understand the aims of Indian logic alongside the approach towards logic and signs by Peirce. Peirce's ideas about signs share a common conceptual space with Dignāga and other Indian logicians. Therefore, it seems reasonable to claim that the ancient and medieval Indian logicians who based their logic on the nature of signs understood the essence of logic primarily as what in the Western tradition came to be called as semiotics.

Is Dignāga's formulation of the triple condition of logical sign a precursor to logic as semiotics? Firstly, Dignāga and Peirce are both interested in valid logical conclusions and judgements. Both of them see the sign as the path towards judgements of the logical kind. Both of them have a broad view of signs, ranging from material signifiers such as smoke to words and concepts. As a theory of signs, Peirce's classification is much more detailed whereas as a theory of logical sign, Dignāga's conditions do more than Peirce's analysis. For example, Peirce's idea of similarity as used in iconic signs is ambiguous whereas this is exactly what the similarity condition in Dignāga's theory tries to answer. In Indian logic, the sign is used synonymously with reason and evidence. The idea of reason is already inherent in the meaning of a sign since a sign is a sign of something else and it is conceivable that there is a reason for this connection. The question for the Indian logicians consisted in knowing whether the sign 'really' stood for the thing which it was supposed to stand for. Therefore, this involved understanding the reason why one sign comes to stand for another. This could be psychological (by seeing concomitance, for example) or social (linguistic conventions, for instance), yet part of the doubt about inference comes from doubt about the origins of the relation between sign and the signified object. The conditions of similarity and dissimilarity are also attempts to clarify this relation as well as understand the original impulse for making the connection in the first place.

Dharmakīrti's three types of inference, the ones based on identity, causality and non-perception, can be seen as a classification that explains why some signs come to stand for another. Identity is based on similarity and is actually a more comprehensive definition of icon as compared to Peirce. When we say that an oak tree is a tree, our inference is based on a perception of some similarities. In general, it would seem that our 'perception' or inference of universals, such as say cowhood, is based on recognition of similar characteristics and therefore signs in such an inference function as icons.

The causal type, with smoke and fire as example, is illustrative of indexical signs. Smoke is an index, which refers to a fire in that location. Smoke and fire are associated through contiguity, and smoke obeys all the characteristics of an index which Peirce describes as follows: 'First, that they have no significant resemblance to their objects; second, that they refer to individuals, single units, single collections of units, or single continua; third, that they direct the attention to their objects by blind compulsion.'[13] Causal signs are just one type of indexical signs. The interesting question is whether Dharmakīrti's second type can be extended to indexicals in general, rather than being restricted only to causal signs? Or equivalently whether Peirce's large set of indexical signs need to be pared only to causal ones?

Given the insistence of Indian logicians to synonymously understand reason and sign, it is to be expected that the arbitrary nature of sign is not available in the logical formulations discussed earlier. But it would be wrong to say that the arbitrary nature of sign was not known to them, since Dignāga's formulation draws upon his *apoha* doctrine of language.[14] It was also very clear for Indian philosophers such as those belonging to the Nyāya tradition, that words function as signs standing for something else. Although Mīmāmsakas, for example, subscribed to a naturalistic description of words and meaning, the philosophers associated with the logical school, namely, Naiyāyikas and

Buddhists, did not do so. In general, ignoring various subtleties of their theories of language, we can say that it was clear to these logicians that the relation between words and things was arbitrary. In fact, I think it is reasonable to argue that the stringent conditions on a valid sign may actually be a reflection of the problems of arbitrary connection between words and what they stand for. Since philosophy of language was one of the pillars of ancient Indian thought, the influence of these philosophics on logic might have succeeded in making the conditions on signs more rigorous than perhaps it otherwise would have been!

Therefore, if in the first place, the arbitrary relation of sign–signified is what is being sought to be eliminated in the three conditions of Dignāga, then it is no surprise that the kinds of valid signs in Indian logic is highly restricted. On the other hand, we can see that the use of symbolic notation in Western logic, including in the representation of terms in Aristotelian syllogisms, is itself a use of signs. In the premise 'All Greeks are mortals', we can let A stands for Greeks and B for mortals and this sentence becomes 'All A is B'. However, note that this move of letting A and B stand for something else is actually a semiotic one, where A is a sign which stands for a set consisting of Greeks. Symbolising thus is arbitrary and therefore there can be no necessary pervasion relation between the symbol A and the set of Greeks. This use of sign is just like the use of language where words are in arbitrary relation with things. Using a term to stand for something is actually to create a sign–signified relation. For the Indian logicians, this move was exactly the crux of the problem! What is it that allows us to use a symbol to stand for something else? How do we justify replacing the set of Greeks with the symbol A? In other words, what they were concerned about in logic was the foundation upon which symbolism was possible. This is a challenge they offer to the modern logicians to clarify and analyse the presuppositions inherent in the very act of symbolisation.

So, once we use arbitrary symbols, we are not inferring but dealing with issues of language. If we are dealing with issues related to language, then the kinds of questions that arise are very different than if we are dealing with cognitive inferences. For Indian logicians, the use of arbitrary symbols would be a movement into the domain of language and thus outside inferential cognition. This implies that even the attempts to symbolise Indian logic is to misunderstand something essential about it!

5.3 *Signs, Symbols and Theory*

The basic question that is common to both philosophy and science, and not just Indian philosophy and modern science, is the problem of understanding how we move from an empirical observation to a hypothesis, or in other words, how to construct a theory about some observation. We might begin a move of this kind by first describing the observation. Even a mere description needs language, and concepts that belong to a language help us to describe the observation in a particular way. We move from observation to theory in this first step of describing a particular observation in words. Talking about observations is already taking us into the activity of theory-making. But why so? What is it that language does? First of all, the use of language to describe what we observe takes us into a different level, to that of language and not of the phenomenal event. The use of language, which marks a distinct qualitative shift from the universe of observations to that of expression, suggests that the use of signs makes possible the shift from the empirical to the theoretical.

This should not be too surprising. After all, the moment we use language to describe an observation we are already in the world of signs. Words in a language are signs. The most important and fundamental characteristic of a sign is that a sign stands for something else. A word 'chair' stands for the thing chair. So words stand for things,

properties, relations and so on. In the case of language it is often the case that words are arbitrary and are a matter of conventions of a particular linguistic community. There is, in general, no 'natural' association between the word and the phenomenal world the word describes and talks about. But verbal languages are not the only examples of signs. There are many different types of signs as we have already seen in the discussion on Peirce. In the Western tradition that is of relevance to philosophy of science, many influential thinkers have formulated various theories about signs and their relation to knowledge. This also illustrates one fundamental similarity in the *concerns* of the Indian logicians and philosophers in Western traditions, namely, an understanding of the relation between sign and signified, and the role of signs in theory-making.

The questions concerning the meaning and role of signs can also be placed within the larger debate on empiricism and rationalism. Empiricism holds that knowledge of the world needs empirical, observational inputs whereas pure rationalism holds that all knowledge can be guaranteed by human reason alone. Leibniz, seen as an influential philosopher of the rationalist tradition, held the view that we can think and know only by using signs. These signs could be natural, in the sense that we make 'natural' associations between sign and signified or the signs could be artificial, in the sense that we as a community create a set of arbitrary signs to stand for various signifieds. Now, if we can think or know only through the use of such signs, as Leibniz would have us believe, then the real fundamental entities of human knowledge and thought are only signs.

Signs do not grow on trees (although sometimes 'natural' signs do!) and the mind has a constitutive role in creating a whole domain of signs through which we think, express and know. Since there is no knowledge without the mediating role of signs, this leads us to a 'constitutive' theory of knowledge. Theory, enmeshed as it is in a world of signs, is therefore possible only by adding something to the empirical world

and this addition consists of the human activity of sign-creation and sign-meaning.

Signs play a fundamental part in human thought and they have a primary role in certain disciplines, particularly logic and mathematics. Frege believed that the idea of the sign was a 'great discovery'. He also held the position that ideas and concepts are possible only through the creation and use of signs. An added advantage of particular symbolic notations was that they did not manifest some common problems associated with verbal languages. However, note that sign here refers largely to an arbitrary set of symbols which are created by us with no specific *natural* meaning associated with them. In the same logical tradition, George Boole understood that signs were arbitrary as far as their form was concerned but once they had a particular interpretation then that continued. He further added that the 'laws of signs are a visible expression of the formal laws of thought.'[15]

Cassirer, much influenced by Leibniz, analysed in detail the central importance of symbols and science.[16] For him, the structure of science rests on the 'logic of things', namely, 'the material concepts and relations', and this logic of things cannot be separated from the logic of signs. An important consequence of this approach was his position that 'concepts of science are no more imitations of existing things, but only symbols ordering and connecting the reality in a functional way'. The importance of this view needs to be stressed again, especially the argument that concepts are also semiotic. This is important because of the commonly held belief that the transition from observation to theory occurs through concepts, and that concepts are neither linguistic nor part of a system of signs. The description of observations by concepts is indeed central to the activity of science. The ability to create new concepts is at the heart of the scientific and mathematical enterprise but is not restricted to them. Even philosophical theories generate new concepts. The belief that concepts mediate observation and theory tends to understand concepts as being beyond the symbolic domain

that constitute theories. Concepts, in one view, are objective realities that are already present in the phenomena and so are discovered. But if concepts themselves belong to the world of symbols then they cannot play the mediating factor between phenomena and their descriptions.

The emphasis on signs and symbols leading to their essential role in disciplines such as logic and mathematics is first initiated by the move of creating signs to stand for various elements of an observation. But, as our discussion on Indian logic clearly showed, this emphasis on sign and symbol is not special to the Western tradition. Cassirer observed that thanks to Leibniz, 'at one stroke the concept of the symbol has become the actual focus of the intellectual world'. Alas, Cassirer was over 1,000 years off the mark. As we saw in Chapter 3, Dignāga's logic was actually all about the nature of the sign and Indian philosophers debated and fine-tuned these ideas on signs for centuries.

In the context of science, Helmholtz, Hertz and Duhem considered the essential role of symbols in theories. Helmholtz, influenced by Kant, believed in the constitutive view that knowledge about the world cannot be independent of the organisation of the mind and that signs play this mediating role.[17] In particular, Helmholtz was concerned with the difference between a property that causes a sensation and the nature of that sensation in us. For example, the colour red induces the quality of redness but this quality is dependent on our constitutive apparatus and thus is only a sign of the colour that is present in the red object. Thus, sensations only indicate the effect an object or a particular property of the object has on human subjects. Helmholtz held a view of natural connection for he saw these signs as 'natural signs' in that the 'same sign must be always assigned to the same object.' An important point in such formulations is that a sign of an object is not the object and therefore signs do not 'capture' the reality of the world but they can be faithful to the lawful relations that are present in the world.

In many formulations of the sign, we tend to come across such a view that while signs may be quite different from the object, they more faithfully represent relations if not the objects. This kind of relational realism is also to be found in some theories of mathematics, a discipline that is indebted to symbolisation. This relational aspect is clearly articulated by Heinrich Hertz, another important scientist, who saw symbols as images that mirror the relations in and of objects. Although he too saw knowledge as being constitutive, he privileged the objects which actually determine the nature of the symbols that are created in the mind, even though symbols capture relations and not the objects themselves. The problem in such approaches is that the nature of the mind and its 'necessary' structures are seen to be real, of an order different from that of the reality of an object. This is problematical since it defines reality of the mind in a different way and also does not expect the mind to be understood symbolically like external objects.

Finally, it will be useful to consider Pierre Duhem's conception of a symbol, particularly since there are some elements in it that are quite different from the Indian view of sign. Ihmig summarises five general features of a symbol for Duhem.[18] Firstly, signs are arbitrary and conventional. They do not possess any natural relation and therefore a sign does not have a natural connection with the signified. He also considers signs to be at a different level than phenomena. Thus, for Duhem, smoke cannot be a sign for fire since both smoke and fire belong to the same phenomenal level, whereas if smoke were to be a sign it has to be qualitatively different from fire. We can see that what Duhem posits is similar to the semiotic character of language, where a word is an arbitrary sign but it is also qualitatively different from the phenomenon/object it refers to. Further, for Duhem, signs are always part of a larger connected universe of symbols and therefore cannot be understood in isolation. The arbitrary nature of the symbol implies that there cannot be any truth-value associated with them. However, since a symbol also stands for something else, instead of the truth or falsity we

can only ask whether it is appropriate or inappropriate. Finally, Duhem makes an important distinction between symbols used in scientific formulation and those that arise in ordinary generalisations. This point is similar to the ones made by many others about the difference between concepts in science and those in everyday life. Concepts in science undergo constant test, modification and rectification just as symbols in science are open to complex processes of creation and modification. Given Duhem's belief in the intrinsic relation between mathematics and theories, one can see that his formulation of symbols is very close to the mathematical use of symbols.

With this background, it may be a useful exercise to explore the meaning and role of signs in Indian logic and where necessary compare them with the Western semiotic tradition. It is clear that there is fruitful comparison at the junction of Indian logic, Western semiotics and the nature of scientific theorising. Similarities and dissimilarities between these fields can illustrate some fundamental lessons about the nature of these philosophies.

5.4 *Arbitrary and Objective Signs*

It is worthwhile speculating on why Dignāga used the formulation of signs to analyse inference. What does inference have to do with signs? One answer is that inference is seen as part of our reasoning capacity and reason itself is understood as an objective, mental capacity possessed by humans. For logic, as we know it in the Western tradition, the process of how we infer is not that important, since it is the formal structures of reasoning that are important. How we infer is seen as a psychological question and therefore outside the boundaries of logic as conceptualised by modern logicians in the West. However, in the Indian context, how we infer is central to the problem of inference. The question of how we infer and reason, in the Western tradition, enters through semiotics and the consideration of the symbol.

Semiotics deals with certain issues about signs which logic does not. As we saw in the last section, most of the influential views offer a constitutive view in which the mind plays an important role in the construction of symbols and knowledge. Even the categorisation of signs as arbitrary symbols is a particular description of the process of creation of symbols and hence of the process of reasoning and inference. Therefore, a semiotic understanding is closer to the kinds of questions that the Indian logicians ask.

Further, the erasure of the originary question, namely, how the signs get attached to the signified, is a question that must be recollected in order to understand something essential about the nature of reasoning. Something similar is echoed in Goodman's response to the problem of induction which was briefly mentioned in the last chapter. In the case of induction, Goodman suggests that how a habit gets formed is as important a question as to what justifies an inductive belief in the habit. For all these reasons, one can argue that Indian logic shares common conceptual space with logic and semiotics. It is therefore useful to understand the work of Indian logic also along these lines. Of interest to us is the particular question of whether the structure of Indian logic reflects an attempt at scientifically formulating theories based on some observations.

There is an interesting problem here. Indian logic arises in a culture which already possesses complex philosophies of language and thus responds to some of these issues. The question of arbitrariness of symbols is one such important issue. The relation between word and object can be natural or arbitrary. In the Indian systems, both these views are held. Grammarians and Mīmāmsakas, for example, held that the word–object relation is fixed. Naiyāyikas and the Buddhists, who are the dominant contributors to logic, hold that the word–object relation is arbitrary.[19] Since we are concerned with the logical tradition, we are justified in asking that since words as symbols are arbitrary and conventional, why is it that valid, logical signs are not so? Why was not

there a semiotics of arbitrary symbols? Is it possible that the strong empirical content in these logical traditions came in the way of developing a semiotics of arbitrary symbols? Furthermore, is there a distinction between the arbitrariness of words and that of symbols?

Symbols, in some of the formulations discussed in the last section, are not based on the model of language, although they share the nature of arbitrariness with words. They are rather concerned with exhibiting two features: one, the distinction between the sign and what it stands for, and two, the possibility of what Leibniz calls 'universal characteristic' which will in some sense remove the arbitrariness in symbolic relations.[20] The arbitrary nature of the sign is only in its creation whereas for the Indian logicians the logical sign must have some necessary connection with the signified. Typically, as we have seen in the discussion on Dharmakīrti, the necessary connections are through identity and causal relation. Thus, there is a reason for our recognition of something as a valid sign. The question of validity of signs itself is quite special to Indian logicians, one which immediately negates arbitrary signs. The basic point is that while there can be a sign which can, in principle, stand for anything, the Indian logicians were concerned about finding the subset of these signs which have a special, natural relation with the signified. Since their logic was responsive to the concerns of language, arbitrary signs, for example, linguistic symbols, are already accepted into the system of signifiers. The synonymous use of sign, reason and evidence also points to the problem of viewing signs as being completely arbitrary.

Arbitrary symbols in certain Indian traditions such as Nyāya are exemplified by words. But the idea of a symbol as discussed by Leibniz and others is somewhat different from the arbitrary nature of words. Pierce uses the example of words as symbols also. However, the idea of arbitrary symbol has an expanded interpretation, one which can be analysed by distinguishing between arbitrary symbols which can be both word-like and not-word-like, implying thereby that there

is a notion of symbol which differentiates between word-symbol and non-word-symbol. Arbitrary symbols can be classified in two ways with respect to meaning. Words, although arbitrary symbols, are filled with meaning. Symbols, as used in logic and mathematics, do not have an associated semantic world like the words.[21] So, the relevant question that we need to consider is whether we can have symbols which are arbitrary but do not carry a space of meaning with them. It is important to note that the *meaninglessness* of symbols is important to make a transition into the logical and mathematical symbolical domain, and that this mode of arbitrary symbolisation is different from the arbitrary nature of linguistic words as symbols.

In the brief historical trajectory discussed in the last section, we saw that signs are created by the mind and mediate what we call as knowledge. Hence, knowledge of external things is always constituted by effects that arise from the mind. In the Indian systems, it is clearly this mind-origin of signs which is problematical. The role of the mind is primary even in Indian traditions as can be seen in their theories of knowledge and cognition, which are understood to be mental episodes. Although inference and cognition are mental processes, the question is whether the mind contributes or creates any input which modifies the external object. In this meaning of the term constitutive, Indian systems are not constitutive. For the Indian logicians, their concern was with the nature of a valid sign, which is based on a necessary relationship such as identity or causality, and the role of the mind is to make valid judgements of inference based on these signs. Therefore, it is more useful to understand Indian logic along the lines of semiotics, especially when contrasted to the preoccupation with the debate on whether Indian logic is epistemology or logic.

Here is an interesting paradox. The constitutive role of the mind, in the Kantian sense or otherwise, is a common theme in many of the Western theories that discuss the relation between symbol and knowledge. Cassirer goes to

the extent of remarking that physics does not constitute of 'signs of something objective' but only of 'objective signs'. The paradox is this: Indian logic and epistemology, which are seen to be essentially 'psychological', actually does not offer any simple constitutive picture. In fact, the sign is not described as arising from an activity of mind and hence the enormously complicated attempts to define the pervasion–pervaded relationship.

5.5 *Science and Semiotics*

Signs are ubiquitous. They are everywhere and occur in all areas of human thought. Science too constructs a universe of signs and its discourse is influenced by the ways it uses and interprets signs. Is there a special nature to signs as used in science?

There is indeed a special relation between signs and science, and this has to do with how science understands perception. One of the most important contributions of science has been its capacity to open up a new world of entities and processes which are unobservable by normal perception. The use of instruments extends our limits of perception and allows us a glimpse into a world hidden directly from us. Thus, for science, there are at least two modes of perception, the direct and the indirect. Not that these modes are special to science; we need only to remember the Buddhist argument that inference is an indirect perception. The meaning of 'indirect' in these cases is slightly different. For the Buddhists, indirect meant the capacity to access a domain beyond that of perception. For science, perception itself can be indirect; instruments extend the range of perception in order for us to be able to perceive things which we cannot do with our unaided senses. However, there is an important question we need to consider about this instrumental perception: is this perception an inference? For example, do we really see electrons or do we infer their presence? And if we infer them, can we develop a method by which our certainty of this inference increases?

Obviously, there is no simple answer to these questions. The kinds of instruments that are used in science are remarkably diverse and the meaning of perception itself is quite different in different kinds of instruments. For example, when we use a telescope or microscope we are able to 'directly see' distant or tiny objects. When we see germs in a microscope, we believe that we are really seeing them, just as we see a tree. For science, there is really no distinction between seeing a tree in front of me and seeing germs through a microscope because the eye itself is an instrument. Seeing through a microscope is only an extension of the capabilities of this instrument called the eye.[22]

Also, sceptical questions about instrumental perception are answered in the same way that sceptical questions about ordinary perception are answered. Science accepts to a large extent the appearance/reality distinction and understands that perception has to do with appearance whereas its task is to understand the 'reality' behind the appearance. So the kind of manipulations it does with our ordinary observations is what it does to instrumental observation. But it is not as if there is no inference even in direct instrumental perception. For example, while we may be able to see germs directly through a microscope there is a systematic reasoning process to conclude that these are microscopic entities which are magnified by a certain amount, and therefore their 'real' size etc., are also correspondingly small. So, information about and meaning of these entities are often found by methods of scientific reason, in which inference plays an important role. But as far as the question of perception is concerned, instruments such as telescope and microscope yield direct perception. The fact that the size of what we see does not correspond to the 'real' size is not important because even in ordinary perception we see objects having different sizes at different distances.

There is also indirect instrumental perception. In these cases, what we see directly through instruments is not indicative of the nature of the entity which is perceived unless

we make appropriate interpretation. In the case of a microscope, if I see an object that is circular then it is highly probable that the object is indeed circular (given that the microscope does not cause distortion etc.), whereas for instrumental detection of various sub-atomic particles, my perceptual data would be very different from what the object would 'really' be like. (Sub-atomic particles are of course a bad example since it is anyway difficult to say what they really look like!)

Now we come to the heart of the matter. In the world of instrumental perception, we are always interpreting what we perceive because all that we have are signs that are referring to something else. The reason for this is that scientific realism accepts a universe filled with entities and processes which we cannot access with our normal perception. The world of unobservables is open to us through signs. A bent stick in the water, for science, indicates the phenomenon of refraction. A diffraction pattern indicates the wave nature of light. A falling body indicates gravitational force. Even in the cases of ordinary perception, science is forever inferring that which is 'behind' this perception. Science cannot perceive the hidden forces of nature, the order in nature that controls the world. It has to infer all the elements of this order. This extends from inferring objects like electrons to fundamental laws of the world. Given its immersion in the semiotic mode, knowing well that only signs are accessible to us, it is not surprising that science is fundamentally concerned with knowing what these signs *really* stand for.

Here is the surprise: the signs that indicate something else, whether it is an object or a law, are natural signs! They are signs that are in a necessary relation with the signified. In fact, it is extremely important that signs, which are interpreted by science in experiments, are natural signs. There is no arbitrariness to them. A diffraction pattern always looks the same way, given the particular experimental set up. A bent stick cannot be a sign which indicates the wave nature of light. The diffraction pattern cannot indicate some

other property of light. So these signs indicate particular properties. But what is special to science is that there can be other such 'natural' signs indicating the wave nature or refraction. But each one of these signs that indicates wave nature has to be a necessary, natural sign for the given context/experiment.

This should be surprising because in the Western tradition the emphasis on the arbitrary nature of the sign was very influential as we saw earlier in this chapter. In contrast, Indian logic was concerned with natural signs. The interpretation of signs within the larger world of perception in science involves, like in Indian logic, primarily natural signs. In the Indian case, the question was how would one know that a particular sign was indeed the correct, valid sign. The three conditions given by Dignāga were methods for confirming and strengthening the belief in the sign–signified relation. What I would suggest here is that the experimental methodology does something similar to these conditions.

Before this similarity is exhibited in more detail, let us note two different paths along which we recognise a sign as a natural sign in science. Consider the smoke–fire example. How do we know that smoke is a potential sign for fire? Before we use Dignāga's methods to know that the inferential relation is correct, we first have a hypothesis that where there is smoke, there is fire. In general, there will be prior knowledge which indicates to us which sign is a natural sign and then we can test whether it is indeed so. Here is where science departs quite radically from Indian logic. In experimental observations, how can we know that a particular sign is indicating something else? One way to know this is through knowing some prior theory. Therefore, science illustrates a dynamic method of creating a space of natural signs through prior theorising. I will first discuss examples of how signs in experiments stand for something else and how experimental methodology shares significant similarities with Dignāga's conditions, after which, I will analyse the role of theory in identifying what kinds of signs are possible.

5.5.1 *Signs in Experiments*

The cloud chamber experiment is a simple example. In this experiment, we can detect electrons and use the data to calculate the ratio of charge to mass of an electron. The cloud chamber has an electric and magnetic field. The experimental output, the observational data, can be generated as a photograph which has a lot of lines on it. One of these lines (which look more like scratches on the photograph) corresponds to the track of an electron. There is no direct perceptual content in the scratchy line and we really cannot infer how an electron 'looks' based on this line. However, this line indicates the presence of an electron. If we do not hold a theory that can tell us how an electron would behave under the action of electric and magnetic fields, how to isolate an electron which can first of all be placed under the effect of these fields and so on, we would not be able to interpret a particular line as being indicative of the motion of an electron. But given a theory we can make some inference from the perceptual data.

This process of inferring the existence of an electron from a line in a photograph is similar to the inference of an object from a sign. The line on the photograph is like smoke at a locus. Our perceptual data are only the lines and from a particular line we infer that there is an electron. The line is the sign just as smoke is the sign for fire. Following Dignāga, we can ask how can we be certain that this sign is indeed referring to an object?

Let us first do a Dignāgian analysis on this sign. We want to know if the particular line in a photograph can be a valid sign that indicates with certainty the presence of an electron. The first condition is satisfied as long as there is at least one case. The second condition is that there should be some similar cases. To find an example of a similar case we should look for similar situations where we see both the electron and the photographic line. Obviously, in an experimental situation such as this, the similarity case is equivalent to reproducibility of a phenomenon. The condition

of reproducibility is equivalent to the homologue condition because for controlled experiments two related properties occur together. Why is the reproducibility of an experiment important? We think reproducibility verifies a conclusion, makes it more certain that what we see in an experiment indeed occurs over and over again. In other words, we create a set of similar cases (in the language of Dignāga) each time we reproduce the event. Each of the experimental repetition is different because each time we reproduce the experiment we are doing it at least at a different time, if not at a different place. Thus, every experimental repetition is a potential homologue. Reproducibility is *weaker* than the condition of similar cases but the implication of it is the demand that signs should be present in similar cases. Also, in the world of experimentation, there is always a constant search for finding different experiments which can reinforce the same finding. For example, the many ways of experimentally determining the Avogadro number, all of which gives the same result, increases the confidence we have in the experimental conclusion.[23] The basic idea in this approach is the same as in Dignāga's condition of finding the set of similar cases.

The experimental methodology in science also shows an awareness of the importance of conditions that are like the set of dissimilar cases given by Dignāga. The criterion of dissimilar case is factored in experimental methodology through the interpretation of null results. Such results, which play an important role in science, come closest to Dignāga's third condition. Null results are those where the expected observation is not found and the lack of this observation actually suggests a world fact. Although, like in the above case, there are some aspects of experimental methodology which differ from Dignāga's conditions, it is easy to see that they also share some common concerns. One of these concerns is about finding ways to strengthen our claims about indirect 'perception'. For the Indian logicians, this concerned inferences and for the scientists it concerns interpretation

of experimental results. For the Indian logicians, a conclusion is strengthened if there are similar cases and no dissimilar cases. For the scientists, a conclusion is strengthened if an experiment can be replicated, if the same results are suggested through different experiments and also through null results.

5.5.2 *Signs, Theory and Experiment*

Earlier, I had suggested that what was special to science was the use of theories to identify what signs could be found and where. Part of the validation of the relation between sign and signified arises from this capacity of theory to say something about signs prior to our perception of them. Thus, before we see the line in the photograph indicating the movement of electron, the electromagnetic theory describes how the sign of an electron will look like and under what conditions it will be found.

Science constructs theories to describe and explain various phenomena and entities. The construction of theories is many times an attempt to understand and explain certain observations although there has been for a long time an autonomous growth of theories independent of experimental results, especially in fundamental theories of nature. Theories draw upon experimental observations and experiments themselves are usually inspired by theories. Although it is often thought that most experiments are designed to merely verify a given theory, experiments are sometimes independent of theories, in the sense that they discover facts not anticipated in a theory. However, as science became more and more theoretically sophisticated, observations themselves get inextricably linked with theories, in the sense that theories make sense of what is and what can be perceived.

What is unique to science is the demand that its theories should conform to some experimental observation. Empiricism is at the heart of science, like it is for Indian

logic. The challenge in science is not only to discover or construct theories that best fits the observed facts but also to find ways to keep generating more facts, with or without the help of theories. Understanding the nature of theories, experiments and their relation is to understand the heart of science.

What is a theory? Theory in its most elementary form is generalisation. It is the capacity to say something more than what we see. A theory has concepts, definitions, explanatory structures, description, new entities, use of deductive and inductive inferences and so on. A scientific theory has certain unique features. It not only describes and explains a particular phenomenon but also generalises about a range of similar phenomenon. It can also bring together what are apparently dissimilar events by showing some fundamental principles or laws that they all obey. For example, Newton's three laws of motion and his gravitational law are enough to derive Kepler's laws of planetary motion and Galileo's laws of terrestrial motion.[24] So, unification is a very important element of scientific theorising. Unification is itself closely related to generalisation. When we generalise a given observation to cover cases which are beyond our immediate observation, we are already indulging in the act of theorising.

Hypothesis is also an important part of theories. In order to explain a phenomenon, it is usually the case that a hypothesis is first proposed. Testing a hypothesis includes the demand that it satisfies both the observational constraint and internal, theoretical constraints. These internal constraints have to do largely with logical and mathematical consistency. For example, such constraints include invalid argumentation, wrong inferences, fallacies of reasoning, incorrect calculations and mathematical proofs, wrong assumptions and so on.

The development of concepts is probably the most important component of theories. Ordering of facts and phenomena is also part of the process of creating and clarifying concepts. For example, even the simple idea of

acceleration, which we take for granted now, is not given to us by the world in any obvious manner. Using the concept of acceleration certain properties of motion can be described. Even the observation of acceleration and measurement of it depends on how we conceptualise it. This is a simple illustration of the theory-laden view, for without having developed the concept of acceleration there is no way we can measure or observe it in ordinary motion. While there may be some intuitive idea of acceleration in our experience of motion, scientific conceptualisation clarifies the nature of this concept in detail. In general, there is a constraint on which ideas are accepted as scientific concepts. It is true that concepts abound in many human activities, whether in cooking, playing, learning music or doing science. An important marker of scientific concepts is the potential for measurement of the concept. Following the dictum of Galileo, scientific concepts are those that are measurable. Further, scientific theories, especially those in the natural sciences, are very much dependent on mathematics. The belief that nature and natural laws are written in the language of mathematics is enshrined in the ideology of theoretical science, especially in the natural sciences.

Theories have another important role to play, one that sets scientific theories apart from mere generalisations. They make possible predictions of new phenomena and entities. The predictability of scientific theories is arguably the one dominant reason for believing that science is indeed describing the world 'correctly'. Associated with this is the prediction of new entities, many of which occur as theoretical terms in these theories. For example, the prediction of particles entirely on theoretical grounds makes it seem as if the language of theories really do refer to things in the world. While this may be true in some cases such as the prediction of positron and quarks, it is also the case that there are a large number of theoretical terms in a theory which have no real counterparts. This is best illustrated in models which constitute a theory. Phenomena are modelled in various ways.

The example of atom modelled on the solar system, interaction of molecules modelled on billiard-ball collisions and so on refer to situations and properties that are only ideal but not realised in the world. There are terms in a theory which do not have any observable, measurable content yet they are indispensable to the theory.

In what follows, when I refer to theories I do not mean all these elements of it. I am interested in the *act* of theorising and not in the specific elements that constitute a theory. It is by looking at the origins of theorising, of the conditions that first allow the act of theorising, that we will understand something essential about this act.

Do we need to have a theory before we can make sense of our observations? This becomes an important question because it seems to be the case that we never observe something in 'itself' without a prior conceptual framework which helps us to make sense of our observation. All our observations are placed on a background of many things, including memory, language, concepts and so on. In this sense, perception is not innocent nor is it naive. If this is so, then we are led to ask the question, how much does the background contribute to what I think I am observing? Or equivalently, how do we distil the 'real' nature of the observed from the overall observation which includes the background?

First, let us see how this plays out in ordinary perception and then discuss the specificity of scientific perception. Even in ordinary perception we always seem to perceive more than that is available to the senses. For example, when I see a tree I recognise various aspects of the tree. Some philosophers, including the Naiyāyikas, claim that we also 'perceive,' along with the other properties such as colour and shape of the tree, the universal 'treehood', that is, the essential characteristic that makes a tree a tree. Moreover, even in the case of ordinary perception there seems to be no way of separating the act of reason and the physical act of perception. Our reason, in categorising the object of perception as a tree, is already doing various things: it places

our perception of the object into certain conceptual categories and makes immediate generalisations of various statements. For example, when we cognise a pattern, it is not obvious whether the pattern exists in nature or our mind orders the world in such a way that we think there is a pattern.

So, it is reasonable to believe that our theoretical framework dictates or at least influences how we see what we see. Especially in science, given the complexity of instrumental perception, the observations make meaning, most often, only in the background of a prior theoretical interpretation. This view, as mentioned earlier, is the theory-laden view. My interest in presenting this view is to show a unique aspect of the semiotic world of science, wherein through theoretical reflection, science describes a set of signs that will be found under certain conditions. Now, if these signs are indeed found in the situations that are already described, it is taken as a confirmation that the sign–signified relation must indeed be correct. If not, then modifications to the theory or experiment are undertaken.

More than the problem of theory-ladenness of observations, there is another act of reason related to observation which is very important to science. This is the ability to see patterns in nature and in natural phenomena. This capacity is integral to science because scientists routinely generalise, noting various patterns of disparate phenomena. Patterns suggest not only uniformity but also allow unification. The capacity to generalise, to detect patterns and to unify is also what is embodied in various inferences, including inductive ones. In fact, the search for laws is motivated by a strong desire to explain these patterns, and is based on the belief that patterns and regularity have to have a cause since nature shows an inherent tendency for disorder. So any order is an indication, a sign of hidden forces that shape that order.[25]

We now come to the basic point of similarity in science and in Indian logical traditions. Both of them note regularities in nature, in some phenomena. From the occurrence of these regularities, they infer that there is some essential link

that explains these regularities. The dynamic view of understanding regularities, exemplified in science, describes the origin and evolution of these regularities through various dynamical processes, including through the use of laws. Indian logicians also are attempting to explain these regularities, although on the surface what they do looks very different from what science does. However, they both share something in common: they are both attempting to construct a discourse to explain some observation. The common concern for science and Indian logic is this: how is it possible to go from observations to saying something about these observations and how can we be certain we are correct? Obviously, we need to clarify what the norms of being correct are for both science and Indian logic. What is correct and certain for both are facts of the world. The ultimate arbiter of a theory will be observations for science and also for Indian logicians.

This discussion on the theory–observation issue is only to articulate the basic problem facing the Indian logician as well as the scientist who wants to say something more than mere statements of fact and observation. In this long discussion, I have tried to argue that Indian philosophers seem to be concerned with issues that are fundamental to scientific methodology. This should not be taken to mean that Indian philosophy had anticipated modern science. Absolutely not. All that we can say at this stage is that it may have at the most anticipated some issues in scientific methodology and philosophy of science. Also, it is useful to note one significant difference. Wright argues that a greater distance between data and theory is the best way of theorising as is manifested in many scientific theories. He calls this the paradox of scientific creativity, in that 'the way to arrive at truth is not by sticking closely to the data but by formulating theories that have the least possible dependence on the data.'[26] This independence suggests then that moving away from basic observations leads to better theories. If so, this is a worthwhile challenge to Indian logic where there is a very close comparison with facts at every stage.

5.5.3 *Sign–signified Relation in Applied Mathematics*

In the early part of this chapter, we saw the importance of arbitrary symbols for science. In the previous section we saw how science depends on the idea of natural signs. We have also seen that mathematics is a defining marker of modern science. And given that mathematical symbols are primarily arbitrary, it might seem that as far as the semiotic nature of science and mathematics goes, there is a fundamental difference between them. However, this conclusion might be too hasty. In this section, I want to discuss one interesting aspect of the use of symbols in mathematics. The motivation for doing this is to indicate a formulation that takes arbitrary symbols and creates signs which have a necessary relation with some signified. The implication of this is that a necessary sign–signified relation is closely aligned with formal structures in mathematics.

Symbols in mathematics are usually understood to be arbitrary. I want to illustrate cases where this does not hold true. Although it is the case even in pure mathematics, this process is more powerfully exemplified in applied mathematics.

Consider a particle with some mass. We can choose to let 'm' stand for mass. There is no natural relation between 'm' and the real property of mass. This means that I can choose whatever symbol for the mass that I want. Similarly, the velocity, which is often symbolised by 'v', is in principle independent of the symbol chosen to represent it. This much is obvious but the next step adds an interesting twist. Given m and v representing the mass and velocity of an object, we can construct a new symbol, mv^2. Now, if the earlier symbols were arbitrary, then it should follow that any complex symbol formed from the simpler ones must also be arbitrary. However, the term $\frac{1}{2}mv^2$ is the 'sign' for another property of the moving object: its kinetic energy. Interestingly, this sign for kinetic energy is the valid and necessary sign for it; no other combination of the simpler symbols can stand for

kinetic energy. Therefore, kinetic energy of any object (in classical physics) will be represented only by this sign and no other. Thus, from a combination of arbitrary symbols we seem to have constructed a sign which is in a natural relation with the signified!

Note that we do not assign an arbitrary symbol for the kinetic energy, which we could have done if all we wanted to do was to assign symbols to all the properties. But if we did assign an arbitrary symbol for all properties, including kinetic energy, we would have missed this interesting occurrence of one property being associated in an essential sense with one particular 'sign'. Therefore, this suggests that while it is possible to associate an arbitrary symbol with every property, we might be missing some important information if we focus only on the arbitrary nature of signs. In Western philosophy, there is a strong move towards privileging the arbitrary nature of sign. Ironically, one of the reasons for privileging the arbitrary nature is that it enables construction of a rich domain of symbols, one that is very important both for mathematics and logic.

This shift from the arbitrary to the necessary is not restricted to kinetic energy but is found in all physical concepts that have a mathematical sign representing them. In fact, this natural association is a very important methodological tool for theoretical research, since it allows us to detect where physical concepts could lie hidden in some mathematical description. Earlier in this chapter, I had argued that arbitrary symbols can be word-like and not-word-like. The difference between these types of arbitrary symbols is that the word-like ones are arbitrary but also have meaning associated with them. The non-word-like symbols do not have a semantic space associated with them. $\frac{1}{2}mv^2$ is not only not arbitrary but it now has meaning, which is captured by its formal structure. Although we can still replace this symbol by any arbitrary, meaningless symbol like k, the meaning associated with it obstructs this move.

This question of symbols with and without meaning occurs both in pure and applied mathematics. One of the reasons why mathematics is so effective in describing the real world lies in its ability to match the signs in its discourse with some physical concepts, like the relation between kinetic energy and $\frac{1}{2}mv^2$. It is clear that there is no causal link between these signs and the appropriate physical concepts. But then what gives the notion of necessity in this relation? We can recollect Dharmakīrti's classification of the types of inference as being of own-nature along with causal relation and non-perception. It has been suggested that own-nature inferences are like analytical statements. Associating specific complex signs for specific physical concepts is made possible through definition. Thus, we define kinetic energy to be $\frac{1}{2}mv^2$ but this is not an arbitrary definition. We cannot define kinetic energy in any other way! And in representing kinetic energy mathematically, we can only use this sign or its symbolic equivalents (like $p^2/2m$, where p is the momentum, which classically is equal to mv).

This suggests that the meaning of the sign–signified relation in the use of mathematical symbols for physical concepts needs a particular analysis of signs, such as Dignāga's attempt to understand when a sign is a logical sign. To paraphrase this for the example discussed above, we can ask, when is the sign for kinetic energy one which really stands for the physical concept 'kinetic energy'? More detailed analysis of this issue will take me too far away from what I want to do in this book. I mention it only to emphasise that the notion of naturally related signs occurs in unexpected places.

Mathematics is the best example of a discipline that essentially depends on the power of symbolisation. However, the notion of arbitrary symbols has been given undue importance in understanding the nature of this symbolisation. Applied mathematics, mathematics that is used in the sciences, poses a challenge to the arbitrary nature of symbols that occur in 'pure' mathematics. That meaning accrues to

symbols is a possibility that mathematics has to accept. This is manifested in the practice of applied mathematics in many different ways and also in pure mathematics. I will briefly discuss two uses of symbols in mathematics that demand a more sophisticated interpretation of signs in mathematics, which includes the possibility of certain signs capturing a special relation to the signified.

The first is the mode of what I have elsewhere called 'alphabetisation' in mathematics.[27] This is a description of how mathematics creates its 'alphabets'. Mathematical discourse has an interesting way of representing various mathematical entities. The patterns of the symbols actually communicate information. Symbols in mathematics are usually understood not only to be arbitrary but also meaningless, as discussed earlier. But if we look at how symbols are created, especially complex patterns representing various mathematical objects, then we can easily see how meaning is encrypted into the patterns of the symbols. Therefore, to look upon mathematical symbols as being arbitrary is to misunderstand the creative use of symbols in mathematics. There is an intriguing possibility that by looking at symbols we can know what it signifies by unpacking the meaning of its pattern. That is, the relation between sign and signified could be hidden in the way the symbol is written! One illustration of this possibility lies in the importance of visual form and its role in applied science. From mathematical patterns, physicists can deduce what masses a particle has or what physical concept occurs where in a mathematical description. A discussion of this will take me too afar but I mention this here to illustrate the importance of 'natural' relations associated with certain signs. These are the kinds of signs that are privileged in Indian logic. We thus see new ways of drawing upon the tradition of Indian logic to reflect on contemporary science and mathematics.

5.6 *Explanation and Indian Logic*

Semiotics is an important theme that can help us explore Indian logic along new paths. At many points in the book so

far, I have made allusions to the relation between Indian logic and explanation. The emphasis on natural signs as against arbitrary ones is also indicative of the presence of an explanatory structure. The concluding parts of this chapter will explore this connection between Indian logic and theories of explanation, many of which were briefly described in the last chapter. We will see in what follows that Indian logical arguments are trying to do a job similar to what the models of scientific explanation do, thereby reiterating the foundational similarities between Indian thought and science.

The above discussion on logic and semiotics suggests that it would be a useful exercise to unpack the various conceptual ideas in Indian logic by drawing upon interpretations other than the standard interpretation of logic/ epistemology. In what follows, I will describe how Indian logic exhibits various similarities with other notions such as explanation, hypothesis formation and so on. What is remarkable is that in all these ways of understanding Indian logic, one facet remains quite constant, namely, the close parallels between Indian logic and scientific methodology.

Let me begin with the *nyāya* five-step argument from early Nyāya logic. When contrasted with Aristotelian syllogisms, it is often pointed out that the use of the example and the inference of a singular proposition in the five-step process negate the logical structure of this argument. These observations have led to a continued debate on whether the Nyāya system deserves to be called logic. In the earlier chapters, we have discussed this issue in some detail. I begin with this problem only to indicate that alternative interpretations of this five-step structure are possible.

One useful way to understand the nature of this five-step process, an approach that also exhibits the logical character of it, is to contrast it with explanation. Specifically with a model of explanation, which, although somewhat out of fashion nowadays in philosophy of science, is still very relevant in many ways.[28] This is the deductive–nomological (DN) model of explanation discussed in Chapter 4. Consider the *nyāya*

five-step model. Let me write the main steps in the following manner:

Wherever there is smoke, there is fire.
Like in the kitchen.
There is smoke on this hill.
Therefore, there is fire on this hill.

Consider now the DN model of explanation. This model describes explanation as a deductive argument from some premises, one or more of which is a general law. In Chapter 4, the structure of the DN model was described in the following manner.

The explanation must be a valid deductive argument.
The *explanans* must contain at least one general law actually needed in the deduction.
The *explanans* must be empirically testable.
The sentences in the *explanans* must be true.[29]

We can now clearly see the similarity between the *nyāya* five-step process and the DN model. Recollect that the structure of the DN model was meant to capture a special character of scientific explanation. When we understand the *nyāya* process along the contours of the DN model we can immediately see that it is also concerned with finding criteria for rational explanations. For example, the reason term in the five-step process is equivalent to the law term in the DN model. Note that the exact definition of a law proved to be difficult for Hempel and 'natural generalisations' do the same work as laws in many examples.

The problem is the example and it is its presence that has made many commentators claim that the five-step process is not a logical argument. However, note that it is precisely the use of true, empirical statements in the DN model that makes this an explanatory model. In the five-step process, the example plays a slightly different role. At first glance, it might seem that it is not an empirical statement which is used in the deduction leading to the explanation.

However, we can see that this is a true, empirical statement lending support to the general law and thus can be taken as part of the explanans. It is also a true, empirical statement related to the case in question because in seeing smoke on a hill we recognise that it is the same kind of smoke as in a kitchen. Thus, the example adds empirical strength not only to the general law but also to the particular case in question, namely, smoke on a hill. Furthermore, Hempel in describing the DN model notes that the 'concept of law will be construed here so as to apply to true statements only.'[30] How do we know that the law is true? In the *nyāya* process it is true by virtue of the similar and dissimilar examples. Thus, this process makes explicit the reasons for believing in the truth of the reason (law) whereas this is a hidden assumption in the DN model. The similarities with the DN model should make us realise that the five-step process is primarily a deductive process just like the DN model. Both DN and the *nyāya* model use examples (or empirical statements) as part of their structure and this is precisely the strength of a scientific explanation.

The *nyāya* process, when looked at as a model of explanation, clearly demonstrates a preferred form of explanation, one that is similar to the DN model. The Naiyāyikas want this model of explanation to be distinguished by some features, a model that would stand the test of reason and rationality. So, they explain a particular proposition by using a general law (*hetu*, reason) and citing an example. This structure of explanation is a deductive argument and that is the useful insight from the similarity with the DN model. Moreover, the premises in the DN model must be true; the example or boundary condition is also an illustration of this condition. Furthermore, in this explanatory schema there can be no premises with empty terms or imaginary and abstract entities. Therefore, the DN model illustrates all the important elements that characterise the *nyāya* process. Thus, we can argue that the *nyāya* process is not

confusing the inductive and the deductive, nor demanding that logic be empirical through the mention of examples, because what it is really doing is giving us a model for reasonable, scientific explanation of a phenomenon, namely why we think (infer, cognise) that the hill has fire.

It is also important to note a significant difference between the DN model and the *nyāya* model. The difference is that the DN model explains a world fact, such as why a stick appears bent when immersed in water. The *nyāya* model does not explain physical characteristics such as why the hill should have had fire. It explains why we infer that it has fire. Actually, what is being inferred in this case was itself a matter of debate. For example, do we infer fire or do we infer that the hill has fire?[31] Or is it, as one Naiyāyika had it, that our inference is that 'this smoke possesses fire'?[32] It is not important as to what we accept as being inferred. What is important is that the explanation is of an 'inferential fact' and not of a physical fact. However, what is noteworthy is the creation of a schema that is similar in both these cases.

The striking similarities between the *nyāya* process and the DN model of explanation must make us consider the possibility that it may be useful to understand Indian logic not only through the usual categories of deduction and induction but also through the theory of explanations. The fact that the five-step process of inference is called inference-for-others also suggests that this is an explanatory model to explain how a particular inference is made. (The similarity with the illocutionary theory of explanation, which argues that explanation is that which succeeds in producing understanding in another person, may be noted here.) Also, the conclusion being a singular proposition, which was seen as a weakness of the logical structure, follows if we understand this process as one of explanation. Thus, what in the context of logic was seen to be weaknesses in the Indian system become strengths when viewed as explanation.

It is well known that the DN model does not cover all scientific explanations. We have also seen some other

problems with this model in the last chapter. Nevertheless, it is an important model as it clarifies how scientific explanations can be distinguished from general arguments, how we can characterise the unique nature of scientific explanations and so on. Understanding Indian logic along the contours of explanation, helps manifest its close relation with scientific activity.

Ganeri is one of the few who even mentions the possible relation between explanation and logic.[33] He acccpts that we can fit the *nyāya* model into the DN model but seems to indicate his preference for attempts similar to Schayer's, who constructs the *nyāya* model as a formally valid argument. We can argue that the attempts to fit this model into a deductive model are no better than the attempt to fit it into a DN model. However, there is an important reason why the latter should be preferred. As I have discussed through the book, it is clear that the larger Nyāya project indicates strong correlation with fundamental aspects of scientific methodology and the model of explanation fits into this naturally. The following sections will further help establish this 'natural' relation between Indian logic and theories of explanation.

5.6.1 *Explaining the General*

What does explanation do? As discussed in the earlier chapter, explanations offer answers to appropriate 'why' questions. In general, explanation enhances our understanding, takes us beyond just knowing that something is the case. But what do we explain? In most of the cases that we are familiar with, explanation is always about some particular phenomenon. The DN model, for example, uses general lawlike statements in order to explain particular events. However, what explains laws? Or generalisations? More importantly, what kind of structure is needed to explain why these laws obtain? For example, we can use Newton's law of motion to explain a wide variety of phenomena. But how do we explain this

particular law? If we see it as a why-question, then we want to know why Newton's law is what it is. The DN model as such is not helpful to develop an explanation for something being lawlike, particularly because it is itself dependent on laws.

Even the Buddhist model of logical sign illustrates an attempt to explain. I believe that we could very fruitfully interpret the Buddhist system of logic as a model of explanation that tries to explain pervasion, concomitance or *vyāpti*. Suppose we are asked to explain why smoke should always be accompanied by fire. How would we do so? The Buddhist argument can be paraphrased as follows: I want to explain why two properties occur together all the time. The explanation uses the fact that I have seen their occurrence at least once, I am aware of other examples of similar homologues where such a concomitance is present and I know of no dissimilar cases. Thus, the Buddhists are explaining why smoke is always pervaded by fire by saying that we have the given example, we have similar examples as in the kitchen and dissimilar examples as in the lake. Again, note that the use of these examples in the logical argument is not negating the logical structure. Rather, if we read the Buddhist argument as an explanation of why concomitance occurs, or as explanation of a law, then we can see why the examples are an integral part of the reasoning process. It has also been observed that explanations are offered for both why questions as well as how questions. Without going into an analysis of this issue, let me only note here that this ambiguity between why and how also occurs in interpreting Dignāga's conditions. It can be argued that the three conditions are basically explaining how we can have confidence in a particular pervasion relation. Thus, these steps are like rules that can be checked, something like algorithmic rules, which will help us reach a degree of certainty about an inferential conclusion. Here we see another dimension of this logical process, namely, the relation between algorithms/rules and logical argument.

There is an interesting similarity between the DN model and the Buddhist model. The explanandum can either be a particular event such as the explanation of inferring fire on a particular hill or it can be an explanation of a general statement such as the concomitance of smoke and fire. The *nyāya* process explains the particular event and the Buddhist logic explains the general regularity. The original formulation of the DN model by Hempel and Oppenheim describes the structure of explanation of particular facts. In a footnote in their essay they note that their account of explanation is not applicable to general laws.[34] Salmon notes that Friedman's account of explanation as unification is an attempt to explain general laws. Having motivated this connection, it will be important to understand the nature of explanation of generalities and also to analyse the standard argument that differentiates between inference and explanation. Dignāga's conditions for valid sign can be seen as a model of explanation for general relations, such as smoke always being pervaded by fire. What is needed for an explanation of the general?

Friedman argues that by reducing the 'number of independently acceptable assumptions' that explain regularities in nature we create better explanations of the world.[35] He argues that any explanation will have some assumptions and the lesser the number of 'acceptable assumptions' there are, the better explanatory capacity it has. An independent acceptable assumption is based on adequate evidence for it. So the underlying point is that for explanations of generalities we need the notion of adequate evidence. Without making any facile jump, we should note that Dignāga's conditions are basically stringent attempts to discover what could be counted as evidence for the assumed concomitance.

Salmon notes that there are two dominant traditions of explanation, one exemplified by the approach of Hempel based on the view that explanation is an argument based on some law or laws. The other dominant trend is the view held by Scriven and others, based on the connection between

causality and explanation, a view that is well captured by the motto: 'to explain an event is to identify its cause.'[36] Both the above views based upon laws (regularities) and causality, especially the causal mode of explanation, are very much the concern of Indian logicians. In fact, we can ask why is it so important to find causal connections? Why would we want to know the cause of an effect? While there are many answers to this question, one of them has to do with explanation. Knowing the cause (if we can identify it as such) explains the effect far better than not knowing it.

The suggestion here is that we would learn something essential about Indian logic by first beginning with the notion of explanation and particularly scientific explanation. To caricature a long history, one can say that in the West logic came first and then explanation. In the Indian traditions, we can say that (scientific) explanations came first and logic was part of the larger structure of explanation, a point that is part of the claim made earlier that Indian logic can be characterised as one which demands that logic be scientific. However, none of this implies that these logicians had formulated the complex ideas of probability and statistics related to inductive generalisations. For Dignāga, logic was used as a means to cut down the number of possible generalisations and not as an attempt to establish the validity of a large number of them, whereas in spirit the probabilistic and statistical models allow us to work with a large number of generalisations by quantifying to what extent they are reliable. In this sense, IS and similar models are at cross-purposes with Dignāga and later logicians.

Finally, I will briefly consider Dharmakīrti's three types of inference and explore their relation to explanation. Firstly, it can be argued that these three types also answer why questions. Matilal briefly discusses the relation between Dharmakīrti's formulation and prediction. He notes that Dharmakīrti's model can be written as 'G(a) because F(a)', somewhat like causal model 'q because p'. What he means by this is that the inferences described by Dharmakīrti are

statements of the kind, 'a is G because a is F', as illustrated by 'this is oak because this is a tree' or 'hill is fiery because hill is smoky'. However, Dharmakīrti's type is 'predictive' and not explanatory 'for it does not explain why must it be the case that G(a) rather than not. Rather, it states why it is the case that G(a), given that it is the case that F(a).'[37] Obviously, Dharmakīrti's model is doing some explanation. It is explaining why we make a particular inference and not how the causal relation is possible. It is explaining why there is a particular inference among all other possible inferences one can make. For example, looking at an oak tree one could conceivably infer many things: this is living for it is an oak tree; this is not eatable since it is an oak tree and so on. But what separates the inference 'this is a tree because it is an oak tree' from these other inferences? Identity is the explanation for this. Also, what is the correct explanation that says smoke is caused by fire? One can give a chemical explanation or one based on behaviour of gases such as oxygen but these are one set of explanations about the physical fact. The point is that Indian logicians are explaining not these physical facts, not why fire causes smoke, but inferential facts such as our inference that there is fire in the hill. What is important to note is that the structure for valid explanation of such 'psychological' facts has the structure of the DN model. This is indeed striking. To further understand this issue, it will be useful to look at the relation between inference and explanation.

5.6.2 *Inference and Explanation*

It might seem that the interpretation of Indian logic as exemplifying models of explanation might be due to a mistaken reading of inference as explanation. This mistake is very much possible since inference and explanation share much in common. In fact, this is manifested in the belief that explanations are basically arguments. As arguments, they share a common space with inference. Even if this were

to be the case (and soon we will see Salmon's rejection of this position), it would only be that all explanations are arguments but not the other way around. Thus, at the most, one could subsume explanations under logic but not logic under explanation. My arguments about the nature of Indian logic might suggest that the central principles of Indian logic were as much concerned with structures of explanation as with structures of valid argument.

We need to discuss two points before we can understand this claim fully. One is the distinction between inference and explanation, and the other is the notion of contrastive explanation. First of all, why would we think that there is some commonality between inference and explanation? Consider an inferential statement: If smoke, then fire. Can this do the job of explaining? It can if we identify what is to be explained. This inference explains my belief that there is fire at a particular location. It is an answer to the question, why do I believe that there is fire there? My explanation to this question would involve saying I see smoke, and I know that where there is smoke, there is fire and therefore I believe that there is fire there. This is not an explanation of why the fire is present where it is (this could be due to somebody lighting a heap of dry leaves, for example) or what it is in fire that causes smoke but only of my belief that fire is present at a particular place.

Consider Salmon's distinction between inference and explanation. The DN model is an example of explanation as an argument. This belief that 'scientific explanations are arguments' is what Salmon calls the third dogma of empiricism.[38] A consequence of the view of explanations as arguments is that there is a symmetry between explanation and prediction. In fact, this is one of the requirements of the DN model. The explanans should be those that predict the fact to be explained. Consider this common example. Suppose we know all the factors that allow us to predict an eclipse at a particular place. Before the eclipse occurs one can predict the eclipse based on all these factors and after the eclipse has occurred we can use the same facts to explain

why the eclipse occurred. The deductive argument is indifferent to prediction or explanation.

However, once we consider events in the past there is a potential problem. Let me consider the example discussed by Salmon. Suppose we see rings on a tree when it is cut. From those rings, we can infer the age of the tree. That is, from information after the event we are able to infer something about the event. This, for Salmon, cannot constitute prediction since from subsequent facts we can only infer the event but not predict nor explain it. He thus notes that in a model that equates inference and explanation, 'inferences to future events qualify as explanations' whereas 'inferences to the past do not.'[39] He sees this asymmetry as manifesting the asymmetry present in causation where a cause always precedes the effect, thereby suggesting once more the strong links between causality and explanation. For all these reasons, Salmon argues that explanations cannot essentially be arguments.

It is not clear that Salmon's critique is a substantial one, especially for the connection I am making between explanation and inference in the context of Indian logic. Firstly, Salmon sets up the critique in order to motivate a causal theory of explanation. He wants to explicitly have the causal relation in explanation; in Buddhist logic it is already present in their inferential model. Furthermore, the counterexamples deal largely with probabilistic cases, those which are really not in the framework of Indian logic. However, there are questions which we need to further consider. Does Indian logic conflate explanation and inference? Does it have a view of explanation which is limited only to an inferential model? These questions can be answered only when we have a detailed theory of explanation in Indian philosophy, one which is not limited to Indian logic.

5.6.3 *Inference to the Best Explanation*

I believe that it is reasonable to hold that Indian

argumentative structures, which I have argued are best doing the job of explanation, in a sense reflect the issues that arise in contrastive explanation. In the last chapter, we have already come across a description of inference which naturally relates inference and explanation, namely, inference to the best explanation (IBE), which suggests that we infer the best possible explanation of particular phenomenon. IBE begins with the question of why we make the particular inference that we do and it answers this by saying that we infer that which best explains the case at hand. For example, if we see a wet road, we infer that it has rained because the fact that it has rained is the best explanation of the phenomenon of a wet road. IBE has also been understood as choosing the best hypothesis among other possible hypothesis based on its explanatory capacity. There are many possible hypotheses that can explain a wet road. But if we conclude that the hypothesis that it has rained is the best possible explanation, then we infer that it has rained.

IBE provides yet another vital link in understanding Indian logic as explanation. It is important to understand the role of hypothesis in this logic. The *nyāya* five-step process begins with a thesis which states what is to be concluded with certainty. So, for example, the first step in the five-step process would be the thesis that the hill possesses fire. The thesis in this process is actually like a hypothesis. It is a possibility which can be tested, confirmed or disconfirmed. A hypothetical statement is characterised by the fact that we are not sure whether it is right or not, whether it is tenable or not. A hypothesis can be understood in different ways. Poincare's description of hypothesis indicates their multiple facets. He notes that there are several kinds of hypotheses; 'some are verifiable, and when once confirmed by experiment become truths of great fertility; that others may be useful to us in fixing our ideas; and finally, that others are hypotheses only in appearance, and reduce to definitions or to conventions in disguise.'[40] The processes of logical reason, inference, theorisation etc., are those which help to change the uncertain state of a hypothesis to a state of certainty or high probability.

It is not only possible but also desirable to look at statements in Indian logic as hypotheses and their structures as explaining why a particular hypothesis is correct. The awareness that a particular hypothesis is indeed right transforms a hypothesis into an inferential conclusion. The steps in the five-step process or in Buddhist logic constitute an explanation for why the particular hypothesis is sound. So, in this sense, the logical process in Indian thought allows us to choose the hypothesis which best explains.

One can ask why it is not so in Western logic. What stops us from saying that every inference we make is actually a hypothesis and that the inferential process leads us to the best hypothesis based on explanation? Or that these inferences exhibit an explanatory character? Basically this has to do with the fact that explanation, particularly scientific explanation and IBE, needs some empirical data. To explain something is to explain some event, some phenomenon. These are accessible empirical data. This means that inferences that deal with empirical observations, such as induction from observations, are those that are amenable to explanations. In Western logic, there is really no reason that is sought for making particular inferences. It is often believed that we make these inferences because that is the way we think, because logic exemplifies 'laws of human thought'. Thus, in inferring we are not really concerned with how we reach a particular conclusion whereas for Indian logic this is precisely the issue. However, note that this does not mean there are no 'laws of thought' since similar deductive argument lies at the foundation of Indian logic. Where Indian logic differs from the Western tradition is that logic is not completely about 'laws of thought' but must be understood as a necessary combination of the 'laws of the world' and 'laws of thought'.

Also, since existential commitment to logical terms is not necessary in Western logic, inference is decoupled in principle from explanation. Since Indian logic makes no commitment to empty terms and the like, their logic is always a logic of the empirical and this brings inference and

explanation naturally together. Although part of a different argument, primarily about the pragmatics of explanation, it is useful to quote Fraassen's comment about explanation one which captures an essential spirit of Indian logic and which exhibits its relation with explanation: 'And while it is true that we seek for explanation, the value of this search for science is that the search for explanation is *ipso facto* a search for empirically adequate, empirically strong theories.'[41] This observation describes well the complex attempts by Indian logicians to find logical basis for empirical statements. In so doing they were naturally involved in creating explanatory structures, particularly structures that are of interest to scientific methodology. It is in this domain where semiotics and explanation meet that a fruitful understanding of Indian logic with sensitivity to its unique characteristics is possible.

6

KNOWLEDGE, TRUTH AND LANGUAGE

Indian philosophical traditions have had a long engagement with questions concerning knowledge and truth. In the development of the basic ideas related to epistemology, we find a rich collection of concepts that describe and analyse the nature of knowledge. Science is primarily concerned with knowledge and its activities are mediated by the desire to know the nature of the universe. Through the knowledge that it develops, science effectively intervenes in the world. Understanding the nature of scientific knowledge is an important part of philosophy of science and for this it draws upon the theories of knowledge from the Western philosophical traditions. Epistemology, which is the study of the nature of knowledge, deals with many issues such as the basic foundations of knowledge, whether such foundations are possible at all, the relation between knowledge and belief, the various types of knowledge that are possible and so on. While some of these issues share a common space with Indian philosophy, there are also some significant differences. The most important one is the description of the process of cognition itself.

In this chapter, along with epistemology I will also consider some aspects of the nature of truth in Indian and Western philosophical traditions. The theme of truth is particularly important because science's engagement with truth is at the heart of the scientific enterprise. I will end this chapter with a discussion on the relation between knowledge and language.

Indian philosophy exhibits a rich tradition of philosophy of language. Every tradition within it has developed sophisticated theories of language, arguably more advanced in their philosophical vocabulary, thematic content and arguments as compared to philosophy of language in other civilisations in those times. Since my interest is in exploring links with science, I restrict myself to those issues that bear upon the use of language by science. I will discuss in some detail a theme which I believe is one of the essential marks of science. This is the belief that what is knowable must be expressible, a view that has significant resonance with the Nyāya view and also with the effability thesis of Bhartṛhari.

6.1 *Pramāṇa Theory*

Indian theories of knowledge develop philosophical arguments to understand the nature of knowing and knowledge. Some of the concepts that are central to Indian epistemology are consciousness, cognition, error, episodic process, valid means of knowing and causes of knowing. There are significant differences in the way knowledge is understood in Indian philosophy as compared to the Western tradition. Western thought, from Plato onwards, begins with a suspicion towards beliefs and opinions, enshrined in the Platonic worry that knowing could perhaps be nothing more than a lucky guess.[1] So, any statement that purports to be knowledge is forever open to the challenge of validation in various ways. In standard accounts of knowledge in Indian thought, knowledge itself is a mental process and knowing is a mental episode, characterised by its capacity to be 'truth-hitting'. For the Indian philosophers knowing is an experience that comes closest to the anecdotal experience of knowledge that led Archimedes to shout 'Eureka' as an expression of his awareness of having 'hit' the truth!

As far as epistemology is concerned, the standard approach in Western philosophy is to begin with belief and then analyse how these beliefs can be justified as knowledge.

Belief and the means of justification of these beliefs are themselves dependent on various sources such as perception, memory, reason and so on. The basic point in this view of knowledge is that beliefs are accessible in a way that makes them available for analysis and examination. In contrast, beliefs in Indian thought exhibit an episodic character. Matilal characterises the difference by noting that beliefs are dispositional in Western philosophy and episodic in Indian philosophy.[2] However, some of the basic questions about the nature of knowledge are common to both these philosophical traditions. In particular, analysis of scientific knowledge can usefully draw upon the philosophical themes that are part of both Indian and Western epistemology.

Indian theories of knowledge are called as *pramāṇa* theory. *Pramāṇas* are means of knowing. They are the valid 'instruments' of knowledge. *Pramāṇa* theory tells us how we come to have knowledge, namely, through different *pramāṇas*, the different means of valid knowing. In this view, there is a double-sided nature of *pramāṇa*, both as a means of knowing and as a cause for knowing. For example, to claim that we 'know' that an object is in front of us is to believe in the veridicality of our perception. It is to say that perception is a valid means of knowing about the existence of an object. It is also true that I see an object in front of me only because I am able to perceive it and so in this sense my perception causes my being aware of the object. However, it would be wrong to conclude that there was uniform consensus among the different Indian traditions on the nature of *pramāṇa* or the kinds of *pramāṇa* that lead to valid cognition.

Matilal sees any *pramāṇa* theory as holding a philosophy of empiricism, either in a 'weak' or 'strong' form.[3] The weak form is an assertion that all knowledge has to have its origins in the senses and while it may have other sources, perception will be the primary means of knowledge. The strong form would imply that there is no possibility of knowledge without sensation: in Matilal's words, 'conception without perception is 'empty'.'[4] Either way, the *pramāṇa*

theory necessitates that every piece of knowledge has an 'accredited means'.

Pramāṇas are the means of knowledge and *prameya* are the objects of knowledge. We know the world and its constituents through the use of *pramāṇas.* Different schools hold the view that there are different *pramāṇas.* The materialist Cārvākas believed that only perception was a valid means of knowledge, while the Buddhists held that both perception and inference were valid means. Nyāya had four *pramāṇas*: perception, inference, analogy and testimony. Vedāntins had six *pramāṇas.* But all these different traditions hold that knowledge is possible only through these *pramāṇas* and that there is an episodic character to knowledge. This means that knowledge, like other sensations, begins or is initiated by some causal factors and is a special type of cognitive episode. But knowledge or a knowing episode has a further special characteristic. It is not only a cognitive episode but it is also one that 'hits' the truth or what Matilal calls the 'truth-hitting' episode. This means that the end-product of the cognitive episode must arrive at some truth. This condition when satisfied by a cognitive episode makes knowledge a 'true cognition'.

The implication of this view is that cognition per se is not a guarantee of truth. There are true cognitions as well as false cognitions. An episodic theory of knowledge is always likely to be committed to such a division. *Pramāṇa* theory is immersed in this problem because it is well known in all philosophical traditions that the *pramāṇas* themselves do not guarantee truth, as well illustrated in the problems of wrong judgement both in perception and inference.

6.2 *Some Basic Themes in Western Epistemology*

In Western philosophy, the study of knowledge goes back to the ancients. Plato's attempt to distinguish between knowledge and lucky guess has influenced the kinds of issues that arise in epistemology. Typically, the movement to

knowledge begins from belief and then a description of how this belief becomes knowledge. Not all beliefs that we have will be true. Even if we hold a belief that we know to be true, it is still not enough to say we have knowledge with respect to that belief. The fundamental question in epistemology is to understand what should be 'added' to a belief to make it knowledge. Chisholm formulates the question of knowledge in the following manner. The analysis of knowledge can be described in three parts. The first is the sentence 'S believes that h'; second is the statement that 'h is true'. Now we need to exhibit a link between these two sentences to reach a state of knowing. So the important question becomes: what do we need to safely assert that 'S knows that h is true'?[5]

An accepted definition of knowledge, one which helps adjudicate a large number of belief statements, is that knowledge is justified true belief. According to this definition, a belief is knowledge if it is a true belief and if it is justified. Although this seems like a reasonable definition, there are many problems with it, including defining what constitutes proper justification. One standard way of analysing how we know, in contrast to merely possessing a belief, is to look at the sources of belief and justification of these beliefs. The standard sources of belief and justification are: perception, memory, reason, consciousness and testimony.[6] Certain logical process and *a priori* knowledge are usually placed under reason and consciousness in this context largely indicates introspection as well as the action of the human will. As is obvious, these sources of belief and justification accepted in the Western tradition share a common space with the *pramāṇas*. We should remember that sources, like *pramāṇas*, are means for generating beliefs with no guarantee that the beliefs so generated are indeed true or not. Some of these five categories also function as a source of justification. For example, perception is both a source of beliefs and justification. My perception of a tree is the source of my belief that its leaves are green. It is also because of my perception that I am justified in knowing that the leaves are

green. Memory is often not considered as a source of belief although it is very important in justifying various beliefs that we may hold. In contrast, memory is not a *pramāṇa* in any of the Indian traditions except for the Jainas.

I will discuss in greater detail one particular *pramāṇa*, namely, testimony, that is common to both Indian and Western traditions. The analysis of testimonial knowledge involves various interesting views on language, a topic which will be considered in some detail at the end of this chapter. This brief discussion on testimony and its role in Western epistemology is also to emphasise the commonalities as well as differences in analysing this particular source of knowledge in the Western and Indian philosophies. Testimony in Western epistemology is seen as a source of both belief and justification, and therefore as a source of knowledge. Some of them may even be basic beliefs in that other beliefs may be built from these beliefs. Testimonial way of knowing is perhaps the most important way of making sense even of other sources of knowledge. Learning from others as a child is an example of knowing based on testimony of teachers and elders. Learning a language itself is dependent on the relevance of testimony. As Audi notes, there is a difference between testimony and other sources of knowledge in that 'perception, memory, consciousness and reason are our primary individual sources of knowledge and justification' whereas 'testimony is our primary social source of them.'[7]

If we look at the various issues that arise in explicating the role of testimony in knowledge we see a striking similarity with concerns about testimony in Indian epistemology.[8] One such is whether testimonial knowledge should rightly be seen as inferential knowledge. The argument for this is that we hear something from a person and then we make an inference about what we really know based on what we heard. Another common concern relates to the characteristics of the person whose testimony we choose to accept. We do not accept the word of everybody. We choose and select whom we believe, meaning therefore that we expect the speaker to have some

characteristics, such as credibility, sincerity and competence. By seeing how children learn, it seems that there are two types of testimonial learning: conceptual and propositional. In various ways, scientific knowledge is also dependent on testimony as a source of knowledge, whether it is in learning science as children or even as professional scientists who gather knowledge from books, journals and peers.

6.3 *Pramāṇa and Causal Theory of Knowledge*

Some writers describe *pramāṇa* theory as a causal, reliabilist theory of knowledge. Mohanty explicitly notes that in the revival of causal theories of knowledge in Western philosophy, perhaps *pramāṇa* theory could be useful.[9] As discussed in the beginning of this section, *pramāṇas* have a dual role, both as means towards knowledge and as causes of cognition. The confusion about the causal nature is particularly exaggerated when we realise that both true and false cognitions are caused. So the challenge is to be able to distinguish two cognitions, one of which is true and the other not true. In a sense this is similar to the problem about inference as a *pramāṇa*. Suppose a person makes an inference which is actually false. The causal nature of cognition, and inference as a *pramāṇa*, makes the philosopher hold the position that the inferential process per se is not faulty. The problem is the fallacy in the elements which are part of the inferential process. This psychological impossibility of making a fallacious inference (which is not a fallacy of the terms in it) is a consequence of the causal picture that is central to the *pramāṇa* theory.[10]

Therefore, in this context, it would be useful to understand the nature of causal, reliabilist theories of knowledge in Western epistemology. As I mentioned above, there are problems in characterising knowledge as justified true belief.[11] However, it is possible to approach the problem of knowledge through naturalistic accounts. Causal theory and reliabilistic theory are examples of this account. In contrast

to starting with justification of belief, a naturalistic account considers knowledge as that which *registers* truth, as in the analogy of the thermometer which registers temperature.[12] A thermometer gives us knowledge of the temperature. This knowledge is not a justified belief but is something which is 'registered' in the thermometer when placed in an object which has a particular temperature. Placing the thermometer in such an object causes some change in the thermometer, from which we get a value for the temperature. In what sense would we now say that we know the temperature of the object? If we accept knowledge as that which registers some truth (in this case a measure of a concept called temperature) then we can claim that we indeed know what the temperature of the object is. At this stage, without reading anything more into this similarity, this kind of explicit connection of knowledge with truth should remind us of the Indian episodic conception of knowledge which is seen as a truth-hitting cognition.

The causal theory of knowledge attempts to find an explicit connection between a belief and the truth of it. Suppose the truth of a belief is exhibited through some causal chain, then knowledge is nothing but 'appropriately caused true belief'. Thus, a belief can be seen as knowledge if the causal story of the belief also guarantees its truth. By seeing a red book I come to know that there is a red book before me. The belief that there is a red book before me is actually caused by the book being in front of me. That is, the book not only causes my belief about its presence but also guarantees the truth of that belief. As we can immediately see, in this view of knowledge, it is difficult to separate means and cause. For an Indian *pramāṇa* theorist, the above example is only an indication that perception is a *pramāṇa* and it exhibits a dual character of being source and cause.

Even if the cause of a belief can be identified, it is still a matter of doubt whether that alone can lead us to knowledge. Audi gives the example of testimony where I come to have a belief because someone tells me something on the basis of

their *knowing* about it.[13] But my knowledge is dependent on the reliability of the person whose testimony causes me to have my belief. Now, if the person is unreliable, then that defeats the possibility of my having knowledge based on that person's testimony. What this example suggests is that causal condition of the belief alone is not sufficient but we also need to know something about the reliability of the process of creation of that belief. The better the reliability of the source the better chance I have of saying that I have knowledge based on that source.

The causal and reliabilist theories of knowledge have their share of problems. One particularly difficult problem for causal theory has to do with *a priori* knowledge, which by its very definition cannot be caused by some particular experience nor can its reliability be of any concern since they are indubitably true.

A deeper problem lies in describing what we accept as being reliable. Audi gives the example of vision, which is otherwise quite robust as far as reliability is concerned, but is still dependent on various factors that allow proper perception to take place. So, under what conditions is vision seen as being reliable in the production or grounding of knowledge? This problem is illustrative of a larger one: it is possible to have more than one reliable description of a particular perception? If so, how do we choose between them?

The various problems encountered by the causal and reliabilist theories of knowledge in Western epistemology have largely to do with the way in which knowledge is conceptualised in terms of belief, truth and justification. The different counter examples to both these theories also suggest that any theory of knowledge which takes beliefs to be dispositional, along with an ontology of propositions and the like, will face these problems. This is especially so in the causal model. Beliefs as dispositional run counter to a fundamental presupposition of the causal picture, namely the immediate temporality of the causal process. In *pramāṇa* theory, the episodic nature of knowing directly satisfies the

imperative of the causal sequence. Further, it is important to note that just because there is a cognition it does not always have to be true. As we have seen earlier, false cognition is an integral part of the *pramāṇa* formulation. The *pramāṇa* theorists are well aware that we are always liable to make mistakes in our perception, inference and so on. The point to learn from this is not to deny these sources their fundamental role in causing and validating beliefs, but to be careful that we do not subscribe to false conclusions that arise from various fallacies.

Moreover, the *a priori* issue should not matter to the *pramāṇa* theorists since it has been argued that Indian philosophy has no *a priori* knowledge, especially in the way it is understood in the Kantian formulation.[14] In the case of reliabilist theory, the example of testimony is apt, especially since *pramāṇa* theory, in which testimony is accepted as a *pramāṇa* (at least by many Indian traditions), develops various methods to check the reliability of the speaker.

6.4 *Scientific Knowledge*

What is special to scientific knowledge? Science exemplifies the larger philosophical issues present in empiricism and rationalism. In fact, it brings them together in a highly successful manner even if the philosophical understanding of how this is possible is not always very clear. The idea of knowledge is central to science since it is committed to the belief that its descriptions and explanations of the world are not only different from other possible descriptions but they also correctly capture the way nature really is, meaning thereby that its knowledge statements are true of the world.

Knowledge in science is normally understood at a more simplistic level than analysed in epistemology. In fact, the concerns about belief, lucky guess and so on do not play any significant role in scientific knowledge. First and foremost, scientific knowledge is pragmatic in nature. It is interventionist in spirit and therefore, any statement is

accepted as knowledge if something can be done using it. Nevertheless, there are some common concerns in a philosophical understanding of scientific knowledge and the scientific activity of producing knowledge. First, the notion of truth is extremely important. Scientific knowledge is about truths of the world; scientific processes generate these truths. Therefore, any analysis of scientific knowledge has to engage with the relation between truth and knowledge. But before analysing this relation and through it the relation with Indian philosophy, I will make some brief remarks on the nature of scientific knowledge. Theories in science are an important agent in the creation of scientific knowledge. We have already discussed some aspects of theories in the last chapter. In what follows, I will focus on some issues about scientific knowledge which I have not mentioned there.

Is there something special to scientific knowledge as compared to other knowledge systems? A common answer to this question is that science deals with the empirical world; its description of the world should be objective and repeatable; every statement of science is open to challenge and so on. In other words, scientific knowledge is fallible. This means that every statement of knowledge and truth in science is potentially open to correction or even complete rejection. It is worthwhile noting that Nyāya holds a fallible theory of knowledge. What Nyāya and science share, among other things, is the commitment to realism, particularly realism of the world and the many constituents which are needed to sustain such a realist view.

Related to this is the idea of approximation which is an important concept in scientific knowledge. Approximation arises in any activity of comparison and primarily science is an activity of comparison between its description of the world and the world 'as is'.[15] The emphasis on quantification and measurability in science reflects the importance of approximation because it seems easier to compare on the basis of quantified parameters instead of making general observations about similarity or dissimilarity. Standard

accounts of scientific epistemology consider this idea of approximation as an important indicator which distinguishes scientific knowledge from other types of knowledge.[16] Normally, the idea of approximation in science arises as follows. In making an observation we may find that the measured value is not the same as an expected value, say a value that is given by theory. Approximation is a measure of the difference between these two values. However, although comparison is often related to numerical measure, science also develops concepts which are thought to match with the world. But rarely do we say that these concepts are approximate. Since the conceptual world of science is a very important component of it, the idea of approximation in scientific knowledge is not as essential as sometimes it is made out to be. There is indeed an inherent notion of approximation in the very act of comparison but it must be remembered that there is also much in scientific knowledge which is not approximate in character.

Concept creation is a very important component not only of science but also of mathematics. Although every human activity has its share of concepts that are specific to each one of them, concepts in science are distinguished by certain features including descriptive and explanatory power, measurability, unifying capacity, being open to change as needed and so on. For example, when we look at a moving object, there are certain concepts that best describe its motion. For science, one such concept is acceleration. Acceleration is a concept which science believes best captures a description of particular kinds of motion. This concept is therefore seen to be a 'real property' that belongs to an accelerating body. The 'rightness' of a concept is a match with the correct property that an object or phenomenon has. Since there is also a demand for measurable concepts, there is a numerical comparison possible between what science says and what the world manifests. The lack of exact match between the two leads to the idea of approximation. But at the conceptual level, there is no

approximation in many cases. So when we call scientific knowledge as 'approximate' it is important to realise that some numerical results may be approximate but there is much more in the domain of scientific epistemology which is not approximate in any sense. Acceleration is not an approximate concept. It can be fallible in the sense that a more nuanced description of acceleration may be developed or this concept may be replaced by something else. However, as long as it is used, it is not approximate in any sense of the word. So also for mathematical formulations. Specific formulations and specific mathematical entities are not approximate at all. In fact, approximation is anathema to mathematics, even in the case of numbers. Conceptually speaking, no two numbers can be approximated to each other, since any number, say 5, is always completely different from another one, however close to 5 it may be, such as 5.001.

It is worthwhile considering whether scientific knowledge is best understood in the language of justified true belief. First of all, we need to analyse the nature of knowledge in science before we understand it in terms of beliefs. I am not sure that analysing scientific knowledge in terms of beliefs, which are then to be justified, makes much sense. The problem is that in science, in the contexts of creativity, discovery and justification, beliefs arise in very specific contexts. The kinds of belief statements that can be generated in scientific activity are not unbounded but constrained in various ways. The mechanism of belief creation is essential for understanding the kinds of beliefs produced in the scientific activity. This, therefore, dilutes the emphasis placed on justification of beliefs. For example, it is not that there are beliefs such as 'there is an electron' or that 'the earth goes around the sun' which then require justification. Prior to this process of belief creation are reasons which initiate these beliefs. Therefore, what is important in scientific knowledge is to analyse the causes of certain beliefs. The notion of belief in science has different connotations than

the common understanding of belief. This has to do with the fact that the causes of beliefs are important in understanding their claims. So, a statement on the order of belief in science is like a hypothesis. A hypothesis is understood to be tentative and possibly true. And the causes, which lead to the formation of particular hypotheses, give an inkling to the kinds of justification that are possible. In other words, not only is a causal story of beliefs more commonly present in science but also these causes indicate the kinds of 'justification' needed. Many times, the way in which the belief occurs also acts like a justifier. In fact, the originary question of epistemology traced back to Plato's worry about differentiating between a lucky guess and a state of knowing cannot be the dominant concern of scientific knowledge.

Belief-making in science is actually a critical process. It is not easy to create a domain of belief statements in science. In ordinary experience, there is no cost to creating any belief that I take a fancy to. The traditional theories of knowledge are to some extent based on the belief that beliefs are free and are to be had easily. This lack of critical thought in the creation of beliefs then demands a stringent set of justificatory conditions in order that beliefs can be called knowledge. In science, however, beliefs are not free and have to be carefully constructed. To create a statement in science, on the order of a belief statement, is to know the language of a theory and to understand something about that theory. This means that there is already a filter to the creation of scientific beliefs and this filter defines how and why scientific knowledge is not best understood in terms of some traditional epistemological arguments in the Western tradition.

These views are commonly illustrated in scientific practice and discourse. When observations are interpreted within the framework of a theory, some hypotheses are framed. There are identifiable reasons as to why those hypotheses occurred in the first place. For example, suppose based on various observations we come to believe that the sun is moving

around the earth and that the earth is stationary. This belief is derived from a set of observations and our interpretation of those observations, perhaps with the help of some theory. The point here is that the belief is generated by specific inputs and both the belief statement and the justification arise from the observation data. This is another way of understanding the theory-laden view discussed earlier.

Moreover, the most crucial aspect of scientific knowledge has to do with the notion of truth. The priority given to truths of the world, which science believes it only manifests and articulates, makes a theory of knowledge a theory of knowing the truths and not necessarily of justifying beliefs. This has important consequences and I discuss these in the following section.

Thus, a useful model of knowledge that can well describe scientific epistemology is a causal, reliabilist and fallible model, one that also prioritises the notion of truth. A theory of scientific knowledge should also reflect a modified version of what constitutes belief by looking at how beliefs are caused. If we are looking for a theory of knowledge that manifests some, if not all, of these characteristics, we need to only look at the *pramāṇa* theory in general and in particular at the Nyāya tradition. They offer a framework which may be as relevant to an analysis of scientific knowledge as some of the theories in Western epistemology.

There is much of the language of the psychological that is kept hidden in the language of scientific knowledge. Hiding the psychological is a rhetorical strategy not only in science but also in other disciplines in modern Western thought. In contrast, the explicit use of the language of the psychological in Indian philosophy and logic has been interpreted to imply the inability of Indian thought to remove psychology from philosophy and logic. Ironically, the reference to psychology in Indian logic is part of a larger attempt to establish objectivity, even when described in terms of psychological elements. In the case of science, the psychological is not explicitly considered or mentioned. I would like to suggest

here that just as much as Indian logic can be rewritten to remove explicit psychological references so too can science be written to explicitly show its commitment to various psychological terms in its discourse. Unfortunately, this is a project that does not belong to this book.

6.5 *Truth in Western and Indian Philosophies*

Trying to define truth is notoriously difficult. In both Indian and Western philosophy, the idea of truth is very important for epistemology. I will briefly describe some of the theories of truth in both Indian and Western contexts.

The standard accounts of truth are the correspondence theory, coherence theory, minimalist theory and the pragmatic theory of truth.[17] Standard accounts of knowledge also follow a similar classification such as correspondence and coherence theory of knowledge. Correspondence theory of truth (and knowledge) is based on the belief that there is an external, mind-independent world and truths of the world are objectively accessible. The truths of the world, in this sense, are just how the world is, what the facts of the world are. The coherence theory of truth claims that there is no completely independent sense of truth that is available to us. Instead, what we have are truths in a web which are in various kinds of relation with each other. We accept as true that which coheres with other truth propositions. Although the coherence theory of truth shares some similarities with the coherence theory of knowledge, they are quite different.[18] Another theory is the pragmatic theory of truth, made popular by the American pragmatists. In this view, truth is what works and the truth of something lies in what it can achieve in practice based on the claims of that truth.

In Indian philosophy, there are similar formulations of the idea of truth. One of the standard theories of truth is a correspondence theory.[19] Truth captures the identity and essence of an independently real object and thus establishes a correspondence between the world and the set of truths

about it. The second kind of truth is the Buddhist view which Mohanty states as follows: 'truth is the property of causing successful practical response', a view that is strikingly similar to the pragmatists' formulation. A third account of truth is given by the Advaita Vedāntins, who argue that truth can only be defined negatively, that is in terms of cognition which is always fallible and open to be shown to be false. Therefore, truth is possible only as that which is not subsequently proved to be false by experience. They reject both the pragmatic and correspondence theory of truth and place truth within the domain of experience and consciousness.

The above discussion might seem to make facile comparisons between two different traditions. However, what I am interested in doing is to draw attention to the complex conceptualisations of similar philosophical themes in both Indian and Western philosophies.

Mohanty offers an analysis of Indian theories of truth by pointing out to some common strains in the many different theories.[20] He begins by asking what does truth refer to, or what is it a property of? In the Western tradition, he identifies propositions as the entities which attach themselves with truth. As is well known, for Western philosophy, propositions are accepted as real entities, as something outside language. In contrast, in the Indian systems, cognition predicates truth. Instead of saying that 'a sentence is true if it expresses a true proposition' as Western philosophy would have it, Indian philosophies express it in terms of true cognition, a real process related to the knower. But this cognitive process is not entirely subjective in the sense that there is a logical structure of its own which one becomes aware of through reflection on the cognition. It is this structure, necessary in some sense, which makes truth objective. Mohanty further notes that the Indians had different ideas of necessary truth although none of them are exactly similar to the Kantian idea of analytic truth. As discussed in Chapter 3, Indians did not use mathematics as a model for their logic or for theories of truth. The most important characteristic of truth is the

fallible nature of truth, a position which is commonly held by most traditions. Thus, there is 'no truth whose opposite is inconceivable, none that is indubitable. Given suitable epistemic conditions anything and everything can become the subject-matter of doubt, and one can err about anything whatsoever.'[21] However, it should be noted that this fallibilism is with respect to empirical truths only; moral truths have an associated infallibilism.[22]

6.5.1 *Truth and Action in Science and Indian Philosophies*

Is the concept of truth needed at all? Is it even possible to identify some propositions or cognitions as truths? What would we need to validate something as being true? These are issues that will take us far into the philosophical theories of truth. Here, I am interested only in discussing the connection between truth and action, an important framework which is central to both science and Indian philosophies.

Questions similar to the ones above arise in epistemology. Primarily, they concern the mechanisms that define justification and knowledge. The basic question is whether these terms need to be grounded in the mind or in a reality external to the mind. The former view is called internalism, which is the position that the process of introspection and reflection by the mind alone validates justification. In such a case, it is called internalism about justification.[23] Similarly, when we ask how knowledge is grounded or what it is based upon, we might point to factors external to the mind, including the way the world is. This is called externalism about knowledge. Audi notes that the justificationist theories of knowledge (knowledge as justified true belief) in general subscribe to an internalist view of justification whereas reliabilist theories of knowledge follow an externalist view of knowledge. On the other hand, internalism about knowledge (self-knowledge would be an example) and externalism about justification seem to be more problematic.

In some Indian philosophical schools, there is a similar internal, external distinction for determining truth. Nyāya is

a good example, where the question of truth is related to that of action. Mohanty describes the move from truth to action in the following manner, as given by the Nyāya exponent, Vātsyāyana: 'A cognition *has* an object, when the object is being apprehended by a cognitive instrument, because there is successful practice.'[24] The relation between truth and successful practice is mediated, for these Indian philosophers, by desire and practical behaviour. Mohanty understands practical behaviour as being of two kinds: one that is concerned with the empirical, that is of the given world and the other concerned with other-worldliness, which would potentially include non-perceptible entities and actions.

In the case of empirical practice, truth depends on what we do based on our recognition of truth. But what is truth here? Truth is that which is based on thatness and is a statement to the effect that the object is one 'belonging-to-that-type'. The example well illustrating these ideas is the recognition of water as water and then drinking it to quench thirst. In fact, the reverse is often possible where somebody drinks a liquid, finds that it quenches thirst and can thus know that the liquid was indeed water. This is a route to truth (that is to the identification of the thatness of the object) that is catalysed by successful action. Thus, for Vācaspati, 'appropriate practical response depends on knowledge of the object ... not on determination of the true nature of the object.'[25] Therefore, we act in the world without necessarily knowing the 'true' nature of the world or of the objects which belong to the domain of our actions. However, there is some ambiguity in this argument. If action 'does not require determination of truth' but only 'apprehension of the object' then what is the relation between apprehending an object and truth? The problem here is one of defining truth in the appropriate manner because there is in some sense a measure of truth in even apprehending an object. What might not be known is the object-ness, the element of thatness which defines that object. The point is that even if we do not know the 'truth' of the object, we know some other truth,

namely the existence of it. Gaṅgeśa makes an important distinction between knowledge and truth here, namely, that knowledge reveals the object but not its 'own truth'. When we have knowledge of the empirical it is not necessary that action based on this knowledge should lead to the truth. Mohanty summarises this view as follows: 'Knowledge gives a certainty about its object, which gives rise to appropriate practical response; if that leads to successful result (*phala*), one is led to infer that the knowledge was true.'[26]

How would we know that we have ascertained truth? The view summarised above makes inference a path to truth, an inference that is made after successful action. The ascertainment of truth, the knowledge of truth, is either intrinsically known or it needs further action/confirmation. The latter position would lead to infinite regress since every confirmatory cognition would need another confirmatory cognition and so on. But this regress is contained if cognition of result is 'intrinsically true' or if one does not doubt the validity of the cognition although 'in principle' doubt is always present. We can thus see a similar formulation of internalism and externalism related to truth. Internalism with respect to truth would imply that our awareness of truth depends only on processes such as introspection and reflection on our cognition in contrast to needing further 'external' inputs such as confirmations and so on. Mohanty thus makes the important point that Nyāya fallibilism does not become scepticism, because cognitions of empirical objects are not 'generally doubted'. Moreover, these provide the grounds for successful action.

While this formulation in the case of empirical objects can be related to successful practice and thereby to an idea of truth, what about cases where there are non-empirical results where we cannot really ascertain whether the action has been successful or not? Mohanty gives the example of performing certain sacrifices, as recommended by the scriptures, in order to go to heaven. In such a case, it is generally accepted that action alone is not an indicator of

truth but some prior knowledge of truth is necessary. Thus, in the cases of the non-empirical, truth has to be understood in a manner distinct from successful action. We must be aware, however, that some traditions, for example, the Mīmāmsakas oppose even the possibility that action is possible without knowing truth.

I think it is clear that there are two points in the above discussion that resonate closely with the practice of science and the notion of truth in science. One is the association between successful action and truth. And the other is the need to formulate an idea of truth when non-empirical results are involved.

It is worthwhile to reflect more on the idea of truth in science and especially the relation of truth to the empirical world. As we saw above, the *nyāya* argument concerns the distinction between knowing the real and truth of the real. There is a larger issue here, one about the nature of reality. If we are aware of an object, external to us and mind-independently real, then why do we need the idea of truth? There is a distinction to be made between the truth of the claim that there is an object which I perceive and the truth *of* the object. Empiricism (and realism in general) might imply that knowing that an object is there in front of me is one type of truth, if we insist on invoking the idea of truth for this case. The other truth that is possible is the truth of various aspects of the object which I perceive. And these truths are accessible, at least according to the views discussed above, through successful, practical action. What is the implication that truth is available through action? First of all, it negates an excessive preoccupation with a rationalistic approach to truth. It also avoids the various pitfalls of meaning other than that related to practical action. In this sense, this view of truth is reminiscent of the American pragmatists' description of truth as one related to practical use.

For any worldview that subscribes to robust realism, there will be a canonical connection between truth and action. This is well manifested in science. What is the nature of

scientific truths? First of all, scientific truths are truths about the world, about how objects are, what kinds of objects there are, the structure of natural laws, description of processes and so on. How does science recognise these as being true? When we perceive an object, the question is not about the truth of the existence of the object but truth of something about the object. This is commonly expressed by talking about the properties of the object. So, truth here is truth about some properties which the object has. And the problem is that we really do not know what properties an object 'really' has and in many cases they have to be discovered. The philosophical theme, which deals with similar kinds of issues, is that which distinguishes between appearance and reality. In this view, how the world appears to us need not be the way it really is and the task of philosophy (metaphysics) is to discover this underlying reality or structures of reality. Science too subscribes to a similar view in a foundational sense but at the practical level it believes that knowing the reality behind appearances is possible only through practical action. This includes intervention in various ways, to use the idea of intervention so effectively described by Hacking as a means to understand scientific realism.[27]

The essence of experiments in science is a reflection of the priority given to practical action as a means towards discovering the truths of the world. Experiments confirm something about the world, some fact of the matter. For example, if electrons really do have a negative unit charge then an experimental confirmation of it is a confirmation of the truth of that statement. And experiments are primarily related to the very idea of practical action. Successful action is equivalent to successful experiment and in general to creation of successful technology.

It is obvious that the kinds of truths based on action, which the Indian philosophers were concerned about, are very different from the kinds of truths that science describes. But focussing on this difference might make us overlook their common approach to the notion of truth. It is this

commonality of worldview that is also exhibited in Indian logic and its relation to semiotics and scientific methodology.

As discussed in an earlier section in this chapter, truth is an important concept for science. To know something is to make a commitment to the truth of that statement. Sometimes these truths are context-dependent but nevertheless science makes a commitment to their truth-value more than their knowledge-value. This only suggests that science views knowledge as a process that takes one towards truth. There is a temporality to knowing that is not present in truth. Temporality of scientific claims is potentially a problematic idea for science and in this tension between knowing and truth, it is truth which is privileged. This is also manifested in the priority given to mathematical truths, especially since mathematics is itself understood as embodying atemporality in an essential sense.

But there is also an important difference in the way science conceptualises truths of the non-empirical and what philosophy does. How can the domain of non-empirical truths be accessible to us? In the example given by Mohanty mentioned above, the non-empirical claim of going to heaven by doing some sacrifices makes the Naiyāyikas delink truth and action in such cases. But this is perhaps too hasty. For science, the link to truth and action continues to be important even in non-empirical cases. And the key to understanding this link is the notion of inference. Recall that if action and truth are to be linked, it is through inference. From successful action we infer the truth of the knowledge upon which we acted. Suppose we make a truth claim that is not potentially empirically accessible. One example is 'going to heaven' or that 'spacetime is 11 dimensional'. Although we can create a complex and consistent theory that might imply that spacetime is 11 dimensional (as some theories in physics have done), it cannot be accepted as true until and unless there is some experimental confirmation of the same. The suspicion about theoretical statements with no experimental link reflects the continued priority to truth and action in science.

6.6 *Knowledge and Language*

Analysis of language is one of the most important contributions of Indian philosophy. Philosophy of language has been an important part of all Indian philosophical schools. The grammarian tradition, exemplified by one of the greatest works on grammar by Pāṇini, was also very influential in that other traditions debated issues which the grammarians raised, such as word or sentence meaning, *sphoṭa* theory and so on. Almost all the issues we have discussed earlier have engaged with issues such as the meaning of language, the capacity to use language and the relation between the world and language. There are many fascinating philosophical discussions available within the larger study of language in Indian philosophy. What I would like to do, restricting myself to the concerns of this work, is to explore a few issues that are relevant to an understanding of science. These include the relation between language and the world, language and meaning, and the effability thesis.

Indian epistemology has an essential engagement with language and this occurs in the discussion of all the *pramāṇas*. In particular, one *pramāṇa* that some of the Indian schools accept as a valid means of knowledge is *śabda*: word, sound or testimony. While the importance of testimony as a valid means of knowledge derives from the belief in the Vedas, it is often used in the context of teacher or other reliable authority figures from whom one can learn. We have already seen the kinds of issues that are associated with testimony in Western epistemology. Some of the issues mentioned earlier include the inferential nature of testimony, credibility of speaker and types of testimonial knowledge. In the Indian case, the Vaiśeṣikas held the view that testimony is reducible to inference. So, they, as also the Buddhists, did not view testimony as a *pramāṇa*. However, some of the other schools accepted testimony as a *pramāṇa*. The nature of the speaker (or the text as the case may be) is also an important constraint. Thus, for testimony to be a valid source of knowledge, some conditions must be fulfilled, such as: the

speaker must be intellectually competent, the spoken language must satisfy conditions for it to be intelligible and the hearer must be capable of understanding what is spoken.[28]

Various questions about the nature of language arise in the discussion on testimony. Obviously, when a competent speaker utters a sentence and if the hearer makes sense of it, then it tells us something about the nature of language and communication. Of great importance for the Indian philosophers was the issue of word-meaning as against sentence-meaning. A brief survey of this discussion is useful to reflect on the use of language in science and in the ways in which this debate manifests itself there.

What is the basic unit of meaning in language? A language consists of words and sentences, which are ordered in particular ways. They also have a domain of meaning associated with them. Philosophy, both in the West and India, was concerned with understanding the nature and function of language and in particular how language creates and communicates meaning. Navya-Nyāya developed a technical language for philosophy, which was used by many other traditions also. For this tradition, the role of language was that of communication and like in other Indian philosophical schools language was seen 'as a source of second-hand information.'[29] If communication has an important role for language, then it is clear that the possibility of effective communication depends on the hearer's competence and capacity to receive and understand. But what exactly is being communicated? It cannot be mere sounds because then there is no way in which the content (or meaning) associated with the sounds also get transmitted. What carries the meaning from the speaker to the hearer? Do words carry it or do sentences? Or perhaps even larger units? In philosophy of language, the standard debates have been about word and sentence meaning, that is, whether words have an autonomous domain of meaning or do they make sense only when used in a sentence.

It may seem obvious that words carry meaning. After all, we use words to designate and denote things in the world. So when I use the word 'tree' I know that I am referring to the object tree. That is all there is to the meaning of the word. In what sense would we think that words are not the basic unit of meaning and that they should be part of sentences which are then the basic unit of meaning? First of all, should we distinguish between a word as such and sound associated with a word? Also, can we distinguish between a word and the meaning of that word? Only if a word is actually a repository of some meaning, then it might be possible to say that meaning is different from the word and the word only communicates this meaning.

What is the relationship with a word and the way it is uttered or heard? When a word is uttered, it is stretched over time. When we hear a word, we first hear the sound of one syllable and other syllables follow. We hear a sequence of syllables and at the end of it we seem to recognise that it is one single word which is being uttered. So, it might be argued that words in their entirety are actually formed in our minds from a succession of syllables. The Naiyāyikas understand this process as follows: we hear the last syllable and then have a memory of the previous syllables and together they produce a 'perception' of the complete word. Does this mean that the sound of a word is different from the word? After all, when we hear a word, it is actually a series of sounds. The point here is whether a word should be differentiated from the sound associated with speaking it or whether it is entirely equivalent to the sound. As distinct from the Navya-Nyāya position that there is no distinction between sounds and words, Bhartṛhari (c. 450 AD), one of the most important Indian grammarians and philosophers of language, makes a distinction between noises and words. For him, a word has autonomy of its own and is independent of its being produced as a sound. But this leads to a puzzle: if the word is different from the sound associated with the word, then when we hear a word, are we hearing the sound or are we hearing the word?

One influential theory, associated with Bhartṛhari, is the *sphoṭa* theory, which argues that 'a word or a sentence is to be considered not as a concatenation made up of different sound units arranged in a particular order, but mainly as a single meaningful symbol. The word or the sentence thus considered as a single meaningful symbol is called the *sphoṭa*.'[30] Sound, as in the succession of syllables that we hear, only manifests the *sphoṭa*. It is this meaningful symbol that carries with it the meaning of the word or sentence. This theory is a holistic theory of meaning in that we do not add meaning from different words that compose a sentence but get the whole meaning of the sentence at one go as it were, implying thereby that the meaning of a sentence cannot be analysed into smaller parts. The implication of this is that the sentence is the basic unit of meaning but this is in the mind. When we speak or hear the sentence, the meaning in our minds gets manifested by individual words in a particular sequence. Bhattacharyya makes the point that Bhartṛhari's theory, distinguishing sound and word, is actually a distinction between appearance and reality. The reality is the unanalysable meaning of a sentence and language, as we know it, is only the appearance. Bhartṛhari sees the articulated language as being based upon a deeper level of consciousness.

The basic ontological debate in language concerns the reality of the words as against sentences. The details of this debate do not concern us here and for the sake of completeness I will only sketch the basic arguments for both positions. While one group of philosophers (especially the grammarians) argued that sentences are those that are real and words are not, another group, notably those in the Nyāya tradition, argued that words are what are real and sentences are created from these words. These ontological positions also tally with the association of word/sentence with meaning. Even a simple question—what does a name refer to?—has many answers. The Indian philosophers discussed four possibilities in this case. If we take the example of the word

cow, then it can refer to: 'the individual cows, the cow shape, the universal 'cowness', or the individual cow as possessing the cow shape and the universal cowness.'[31] For the Mīmāmsakas, words refer to universals so the word 'cow' refers to a universal 'cowness' and not to particular cows. Nyāya holds that words refer to particulars as qualified by universals, meaning that the word 'cow' means a particular cow along with a recognition of its cowness. The famous Buddhist *apoha* doctrine is based on the theory that words derive their meaning not through denotation but through exclusion. Thus, a word 'tree' is not indicative of the class of trees or signifying the universal treehood but is related to all that is not-tree, such as chair, table and so on. So the meaning of the word 'tree' is given by all that is 'not not-tree'.[32] Dignāga, the Buddhist logician discussed in Chapter 3, used this theory of exclusion to argue against the Naiyāyika view that there are objective universals such as treehood.

6.7 *Technical Language and Mathematics*

It would not be an exaggeration to say that modern science is made possible by the shift to using mathematics to talk about the world. Those who critique this view, point to biology, for example, to argue that the use of mathematics is not necessary there in the way it is for a subject like physics and moreover the kind of mathematics needed in biology could also be quite different than that used in physics. But this is not a serious challenge to the fundamental relation between sciences and mathematics since biology, even those areas that do not explicitly use mathematics, draws much from physics and chemistry, and upon various technologies for their experiments which are all based on mathematics in one way or another. However, there are very many worrisome issues in this project of mathematisation.[33] In the context of Indian philosophy, there are two issues regarding mathematics that will be relevant for our purposes here. First is the way in which mathematics was understood by the

rationalist Indian philosophies. Secondly, although there was no explicit mathematisation of the form that we see in modern science, a technical language, especially suited to express the concerns of philosophy, was developed by the Navya-Nyāya tradition.

Navya-Nyāya developed a technical language for their philosophy. Although developed by them, it was used not only by other philosophical traditions but also in grammar, poetics and so on. I shall briefly state some characteristics of this language, drawing upon Bhattacharyya.[34] Firstly, this language is developed from Sanskrit, is not symbolic but is nevertheless rigorous. It is not a meta-language but is a language that does the job of describing as against expressing, which is what ordinary Sanskrit does. The technical language describes cognised structures. Bhattacharyya isolates three characteristics of this language in terms of its functions. This language is developed so as to state various relations unambiguously. For example, the relation of identity and relation of inherence are stated in a manner that makes it clear what is in a relation of identity/inherence with another. Also, this technical language introduces the idea of limitor to define quantity. These limitors are also used as punctuation. In this construction, we can see one important motivation of developing a technical language, which is to remove the ambiguity of common language and find appropriate language to clearly express relationships. Contemporary understanding of mathematics also points to its special capacity to express relationships, thus suggesting that the Navya-Nyāya use of a technical language for philosophy might have something in common with using a language like mathematics for science.

Mathematics was very much a part of the larger culture in which Indian philosophies flourished. Ancient Indian mathematics made rich contributions not only to disciplines such as algebra but also to those such as astronomy. The pragmatism in traditions such as Nyāya is also embodied in Indian mathematics, in particular its emphasis on algorithmic as against the axiomatic approach.[35] Given the impact of

mathematics on various fields, it is curious, as Mohanty notes, that mathematical knowledge was not sufficiently analysed within the *pramāṇa* theory.[36] One reason suggested by him is that mathematical knowledge is sometimes subsumed under inference, reflecting once more the attempt to take mathematical thinking within the folds of empirical thought. However, he argues that the analysis of numbers and a notion of mathematical proof suggest that mathematics itself should be regarded as a *pramāṇa*.

The nature of number has been a source of fertile philosophical debate. In modern terminology, numbers are dominantly understood as being associated with sets. Numbers were described in an unusual way by Indian philosophers, particularly the Naiyāyikas. It is worth a short summary of their view of numbers, especially since it might illustrate the approach of Indian philosophers towards understanding the nature of mathematics. Numbers usually arise in phrases like 'two cows', 'three trees' and so on. What is the role of 'two' and 'three' in these phrases? Our immediate response would be to say that they are pointing to the fact that more than one cow are present together. Even if there are two separate cows in front of us, what makes us put them together and express that two-ness by saying 'I see two cows'? An analogy might make this clear. Is the above statement "I see two cows' similar to saying 'I see a red cow'? Red is a property of a cow and inheres in it. Similarly, would we want to say that 'two' inheres in the two cows present together?

The earliest categorisation of numbers by the Vaiśeṣika described numbers as belonging to the category of qualities. Vaiśeṣika had seven categories of the reals, of which quality is one. These categories were later adopted by Nyāya as their ontology. Qualities include examples of what we would call properties such as colour, shape and so on. When the Vaiśeṣikas claimed that numbers are qualities they meant that in the phrase 'two cows', 'two' inheres in each of the two cows. Now, just like a red cow is said to have redness, can

we say that each of the two cows has two-ness or that the two cows taken together have two-ness?[37] Without getting into the complexities of this debate, let me only note here that two-ness qualifies something about our perception of two objects taken together and not as distinct individuals.

For a different description of number, we can look to Bhāsarvajña, according to whom numbers are not qualities but relations describing identity or difference.[38] Qualifying distinct individuals together as being two, for example, is only an indication that these two individuals are not the same but are distinct. Thus, relations of identity (which describes the number 'one') and difference are captured by the use of numbers.

What is of significance in these attempts to understand numbers either as qualities or relations is the emphasis on empirical statements to understand an entity such as number. In mathematics, numbers can be defined without restricting them to their connection with the world. One of the standard accounts of numbers in philosophy sees them as abstract entities, meaning that they are not spatio-temporal. Numbers have also been understood as proportions or as related to the notion of sets. In all these approaches in Western philosophy, numbers are analysed independent of the way they are used in talking about the world. The emphasis on understanding numbers in the Indian tradition through their occurrence in the world once again points to the essential empirical tendency of Indian thought. We can argue that the Platonist view of mathematics, which is most often exhibited in the philosophical analysis of mathematics, is not necessarily the correct way of understanding mathematical entities and processes. As mentioned earlier, there has been sustained work arguing that mathematics arises in response to the world and therefore it seems unreasonable to insist that the foundations of mathematics be independent of our world. Now, suppose that mathematics arises in response to the world, that mathematical entities and processes are at least partly empirically influenced, what can we say about

the nature of numbers? The Indian view described above is one possible approach to developing an answer to this question.

6.8 *Science, Effability and Bhartṛhari*

These concerns about the nature of language were very much influenced by particular theories of knowledge held by the various philosophical schools. As I mentioned earlier, the discussion on testimony as a *pramāṇa* gave rise to various debates on the nature of word and sentence, the relation between language and reality, and so on. One important element in this analysis of language was the question whether all knowledge can be accessed by language. This is basically the same as asking whether there can be knowledge which is beyond description by language. Nyāya takes the view that whatever is knowable is nameable, meaning that what we can in principle know will always be expressible in language.[39] There is no knowledge beyond linguistic description, thus negating the possibility of knowledge which is inexpressible and ineffable. Nyāya's thesis of effability, that whatever is knowable is expressible in language, is an important thesis, of great relevance for what it says not only about knowledge but also about language. I also believe that some similar notion of effability is an essential constituent of science for reasons described later in this chapter. The other traditions do not subscribe to the effability thesis as propounded by Nyāya. In fact, Buddhists and others emphasise the importance of ineffability, that ultimate reality is 'unspeakable' and thus outside language.[40]

Matilal notes that support for Nyāya's effability thesis comes from the grammarian Bhartṛhari.[41] Bhartṛhari sees consciousness as the motivating factor of the activity of language. The origin of the word is actually in the deepest level of consciousness.[42] So, knowing, for him, is made possible through words. Without language to mediate between us and the world, there would be no possibility of the revealing

character of knowing. But what of language mediates between us and the world? Concepts, expressed linguistically, illuminates perception, which otherwise would be empty. Matilal notes that Nyāya would not subscribe to this position, since they acknowledge that a knowing awareness is possible without concepts, nevertheless it would still be expressible in language.

The crux of the problem is just this—can there be cognition without language? Can we make sense of perception without language? Since perception is a *pramāṇa*—the most important one among them—the answer to this question reduces to the effability problem. For the grammarians, particularly Bhartṛhari, all cognition and perception is linguistic. For the Buddhists, particularly Dignāga and those following him, perception (at least one level of perception, namely indeterminate perception) is possible without language, a position which was supported to varying degrees by the other traditions.

Since my interest is in exploring the possibility of effability, let me discuss it in a little more detail. Bhartṛhari's position links language to the most fundamental level of human consciousness. Thus, the capacity to use language, to verbalise, is 'immanent in our cognitive faculty.'[43] Our innermost thoughts are actually verbalised, although it may not always be consciously accessed as such. For this to be possible, things in the world should come with their names attached to them and perception of something is immediate, and is mediated through recognition of the word association with the thing.

If language mediates between us and the world, how can we be certain that in so doing language does not distort the reality of the world? Suspicion about language, especially in this mediative role, is often voiced in this manner. The Buddhists believed that the use of language distorts the world although they do not see any way out of using language. In perception, the argument is that we cannot have any innocent perception of an object as-is. Our perception is always

mediated by the concepts our language has, our own felicity with the language and so on. In the case of knowledge, the same problem arises, not the least because perception is a dominant *pramāṇa*. The way this plays out in Bhartṛhari is of great interest to the relation science has with language. This has less to do with language mediating, or in some sense co-constituting, the world than with the capacity of an object to be associated in an essential sense with language, at least with those names and concepts associated with that object.

Let me phrase the problem in this manner. We see an object. We give it a name and describe its properties. Now, the question is if language arises entirely within us, the object should be indifferent to the language used to describe it. We could conceivably describe its properties in any language and it would all be the same. That is, the translatability of the language associated with the object indicates that the object has no special linguistic *demands* of its own. We do not think that the object tree suggests the word 'tree' to us in any sense. We *create* the words which will describe these objects. Since language is conventional, since it is an activity generated by a community, the object per se has nothing to do with it. In the description of the world, movement is from language to world and not the other way around. At least this is an influential position in contemporary philosophy of language. Nyāya too would agree to this view that convention plays the main role in establishing the word–object relationship. In contrast is Bhartṛhari's claim that words and concepts are 'ingrained' upon an object and therefore our awareness of the object is awareness through language.[44] This is the effability thesis that is closest to understanding how science uses language.

Science has an intriguing relationship with language.[45] On the one hand, without language there is no science and on the other, science exhibits a great degree of discomfort in acknowledging language as an integral part of its discourse. This discomfort, part of a larger suspicion of language, is partly compensated by a shift to mathematics, which

presumably does for science what a natural language, like English, cannot. However, science cannot do without natural language and language-use in science is much influenced by this fact. Paradoxically, science is one activity which exhibits a complex use of language. Its texts are multi semiotic, in that it uses many 'language' systems such as natural language, mathematics, pictures, diagrams, graphs, figures and so on. Its text 'binds' these different systems in a single, coherent way that is rarely seen elsewhere in other disciplines.[46]

Science's view of nature indicates the fundamental priority it gives to language. Important scientists, from Galileo to Einstein, described nature as an open book written in the language of mathematics. The task of the scientists, therefore, is merely to read this book and write down all that is written in it. Scientists do not contribute to this writing but only faithfully copy down the book of nature.[47] So, to learn the secrets of nature is just to read how that secret is 'written' in some mathematical formulation. In other words, although science uses language(s) to describe nature, that language does not come from us but from the world around us.

In the context of science, there are two parts of the effability thesis that is worth considering here. One is the possibility that the world has a language of its own and the human subject's role is only to exhibit it as dictated by the world. Two, related to the above, is the belief that everything knowable about the world is indeed expressible, a position which science and Nyāya share. It is for these reasons that Nyāya and Bhartṛhari can offer important insights into the nature of the relationship between language and the world as science understands it. In what follows, I will discuss both these points separately.

What can it mean to say that nature is an open book written in the language of mathematics? Does this commit scientists to accepting that language comes attached to things? Would this imply that the task of scientists is only to read what is already inscribed on things? There is in this

possibility a resonance with Bhartṛhari no doubt but there are also some important differences. For both these views, it is clear that language as convention alone cannot do the job. There is some notion of natural connection between language and world. But there are also two crucial differences. One, for Bhartṛhari there is a basis for language at a foundational level of consciousness and this is a view which may not find immediate sympathy in science. Two, the languages that Bhartṛhari and science see as being embodied in objects are not only different languages but differ in kind. For Bhartṛhari, it is Sanskrit and for the scientists, it is mathematics. But this point aside, the major philosophical issue both these views engage with is the possibility that the world has its own language and our use of language to talk about the world has a best fit with the world when we read off this language.

Since we have discussed Bhartṛhari earlier, I will now consider this issue in the context of science. Why would we think that science commits itself to the position that the world has its own language? There is the fundamental belief in science that nature has the last 'word' in every sense. The image of nature as an open book reinforces this position. The recourse to experiments and empirical observations to validate any statement in science further points to the priority of the world. Science can therefore only express what is there in the world. And since science can only express through language, it has to be able to express the language that is part of the world. But not all elements of a language arise from the world. Science can accept the argument that language is conventional, at least some dimensions of it. But the main question for science is: are the *essential* elements of a description derived from convention-based language or from the language of the world? Here the tension between natural language and mathematics is exhibited clearly. For the scientific worldview to be possible, we will have to grant that natural language in large part is convention bound and therefore in those places where natural language is used

in scientific discourse we do not speak what the world says. But, for science, natural language does not express the essential truths of the world. It is this suspicion of natural language, based as it is on conventions and human interests, that marks the shift of science towards mathematics. And, for science, while natural language does not have the capacity to capture the essential truths of the world, mathematics does and does it very effectively.

The world comes to us already tagged on with mathematical language written on it. Bhartṛhari's theory can be used metaphorically here. For science, ordinary language, a natural language like English which scientific discourse needs and uses, is like Bhartṛhari's surface language. The underlying language, like the underlying deep consciousness, is mathematics. Scientific self-expression is an attempt to go from the surface to the depth. Once we reach that state, once we are immersed in the midst of the mathematical world, we realise the true word–object association.

Is it reasonable to believe that the role of mathematics makes us commit to something like Bhartṛhari's view on the word–object relationship? I think it is for the following reasons. One of the most influential reasons for believing in mathematics as the language of the world is a special word–object relation. This is of course extended to phenomena and processes. This is the view that mathematics or some specific mathematical entities *best* describe a particular object or phenomenon, that there is a one–one relation, which is a natural one, between the world and its description through mathematics. The argument that to know the world is to know the correct mathematical terms associated with a particular object/event is central to the enormously influential observation about the 'unreasonable effectiveness' of mathematics. First voiced by the physicist Wigner, this phrase has captured the imagination of scientists and is often used to express their surprise at the way mathematics seems to work in natural sciences.[48] For Wigner, the unreasonable effectiveness stems from the fact that some physical concepts

are best captured by specific mathematical formulations. Wigner was amazed that the second derivative should so 'correctly' match the physical concept of acceleration. Eminent scientists who have written about this later also seem to find this effectiveness illustrated in the unexpected ways by which some mathematical entity or idea captures something essential about the physical world. The unreasonable effectiveness arises from the surprise that not all mathematical terms fit the description of the world. There seems to be a natural fit between some mathematical terms and some physical processes, like symmetry to groups, fibre bundles to gauge theory and so on.[49] If this idea is extended to natural language, it is equivalent to saying that some specific words alone can best describe some object or event. It would be equivalent to saying: 'A rose by any other name will not be a rose!' Therefore, it is not only words but also concepts from mathematics that best match phenomena in the world.

Assuming this essential inherence of mathematics in the world, what is the role of the human subject? For Bhartṛhari, human consciousness is the substratum where language and world come together without exhibiting any fundamental distinction between them. This view cannot directly be acceptable to science, mainly because it cannot or has not found ways to incorporate consciousness as an entity essential to scientific description. Moreover science's understanding of the mathematical world is profoundly different as compared to its understanding of natural language. It has long been believed that mathematical entities inhabit a world independent and very different from ours. They are the citizens of a Platonic world, a world characterised by entities which are not spatio-temporal. The universality (and eternality) of mathematical truths can be seen as a reflection of this Platonism. So, mathematical language, for humans, is discovered from this Platonic world and is not a human creation. It cannot be conventional in the way English is conventional. Discovering mathematics, in this view, is a lot

like discovering the secrets of our world. Discovering mathematics is to learn to read the open book of the Platonic world and our discovery of mathematical entities and processes is just a reading off from this book.

This belief in Platonism and universalism of mathematics distinguishes, at one level, Bhartṛhari and science's view of language, and its relation with the world. But at a fundamental level, the question of the human subject cannot be denied, even for science. Also, there are at least two problems related to the nature of mathematics itself. Firstly, is mathematics Platonic or is it a product of the human imagination without any Platonism inherent in it? The Platonic view of mathematics has had its share of critics. Humans not only create English, they also create mathematics. If conventions are a part of English, so also are they a part of mathematics. Secondly, what is the relation between mathematics and the world? Is mathematics a separate domain, separately a Platonic world? Or is it indebted to the human and natural world? I think it is reasonable to hold the position that mathematics arises from human interaction with the world and in this sense is as much derived from the human imagination as it is from our experience with the world.[50] This position, coupled with the view that mathematics is the language of the world, can perhaps be upheld only by some variation of Bhartṛhari's theory. If science wants to understand its dependence on mathematics and not just pragmatically use it, then it might find Bhartṛhari's theory of much interest.

The second major thesis of effability that I want to consider here is a variation of the Nyāya claim that 'whatever is knowable, is nameable'. This claim, I suggest, is central to the scientific worldview and actually explains the dynamics of scientific activity. Privileging mathematics is also a part of this worldview. For science, there is no possibility of knowledge of a world outside language, whether it is natural language, mathematics or a mix of both. Even knowledge of the abstract is expressed in language. Whatever is accessible, whatever can be known can be linguistically expressed. I

believe that this basic belief about knowing and language is clearly a part of Nyāya and scientific traditions. Equivalently, for science, there is potentially nothing of which we cannot speak and so nothing about which we can remain silent. Silence indicates ignorance for science and is an indication of a lack of linguistic capability which is needed for knowledge. This lack could be the lack of the 'correct' mathematical terms, for example.

Scientific activity, both in praxis and discourse, consistently exhibits this mentality. Science's fertile engagement with language is part of this view. Science, in talking about the world, realises the great gap between its expressive capacities and the 'reality' of the world. Natural language does not show the capability required to exhibit the truths of the world. Therefore, science uses mathematics as one language to see if it can open up new expressive possibilities. It also uses other semiotic systems, along with natural language, in a continued attempt to generate new narratives of the world. In doing so, it realises that the languages it has are not enough to match that of the world. So, it continues to develop new languages. It is important that we understand mathematics not as one static language but as many sub-languages, all of which are dynamic and growing. The possibility of finding in this large surplus space of linguistic entities some which match the label on the world (to use a Bhartṛharian image) increases when the domain of language increases. Matilal summarises Bhartṛhari's thesis about language as saying that 'words and concepts are implicitly and inextricably mixed up so much that a concept is nothing but an implicit speech-potential, a not-yet-spoken word.'[51] This indicates the possibility of effability as being found in the potentiality that is inscribed in the not-yet-spoken-word or, for science, in the not-yet-written-mathematical term. And the task of science is to find this yet-to-be discovered voice of the world.

The reading of Bhartṛhari which I have offered here does not capture the difficulty in articulating precisely what he was trying to do nor does it take into account various

difficulties in his view. There is another interpretation of Bhartṛharian effability that is possible, one which also exhibits the common concerns shared by science and Bhartṛhari. Such a reading is offered by Probal Dasgupta who notes that Bhartṛhari radically differed from other traditions, including Nyāya, in his understanding of language and its relation with the world.[52] What is important for Dasgupta is Bhartṛhari's belief that total access to reality is not available to any subcommunity of language users. Each of these communities can have partial insight into the world and thus to access a complete sense of reality a collection and combination of languages will be needed. This view allows Dasgupta to understand the multiple semiosis that is such an integral part of scientific discourse.[53] Thus, he notes that 'multiple semiosis becomes essential because each form of labour gives a different, and always partial, access to certain realities, and they have to add up in a criss-crossing fashion, with metaphor bridging the gap from practice to practice, from subcommunity to subcommunity.'

These partial readings of Bhartṛhari show that it is possible to engage with what seem to be archaic philosophies in a fruitful manner. What I have tried to do here is to explore the space of ideas that are catalysed by the rich philosophies of language available in various Indian traditions. The fact that some of them are doing something similar to what science is doing only makes this intellectual exercise more worthwhile! The most interesting exploration in this context is the effability thesis, one that has been argued for in different ways not only by Nyāya and Bhartṛhari but also by modern science.

Ironically, the effability thesis leads science to a paradoxical position because it will necessitate that science acknowledges the foundational role of language in our understanding of the world. If followed through consistently, it will lead science to articulate this thesis: To know the world is only to know *its* language. This position is paradoxical for science, based as it is on a hard-headed belief in the

materiality of the world and in its insistence on the world as the final judge of its claims. At the final count, language is what remains for science and without it, not only is knowledge not possible but it is not even accessible. Any philosophy which claims to describe science must necessarily engage with the issue of science and language, and insights from Indian philosophies of language will be of great importance in this analysis.

NOTES

CHAPTER 1

[1] For example, see Alvares 1991 and Ada 1989. The Project of History of Indian Science, Philosophy and Culture (PHISPC) has published many edited volumes on various aspects of Indian science and technology. See also Chattopadhyaya 1996.

[2] Phillips 1997 (pp. 145–146) notes that Nyāya epistemology conflicts with science, even though it is empiricist and causal realist in character. Although he calls Gaṇgeśa's work as not being 'far different' from science, he also says that 'conflicts with science' are Nyāya's 'most major deficiencies'.

[3] Gadamer 2001.

[4] Ibid., p. 119.

[5] Ibid., p. 119.

[6] Ibid., p. 120.

[7] Ibid., p. 122.

[8] Ibid., p. 122.

[9] See Sarukkai 2002b.

[10] See Sarukkai 2002a.

CHAPTER 2

[1] For example, see Landesman 1997.

[2] For more on this, see Matilal 2002a.

[3] Ibid., p. 65.

[4] Phillipps 1997, pp. 52–53.

[5] Potter 1977, p. 154.

[6] Matilal 2002a, p. 73.

[7] Mohanty 1993, p. 105.

[8] Ganeri 2001a, p. 158.

[9] Somerville 2002, p. 13.

[10] Ibid., p. 15.

[11] Mohanty 1993, p. 110.

[12] Vidyabhusana notes that there are five types and the fifth one being 'irregularity of non-perception' which is similar to the fourth one but is about the proper classification of something not-perceived. See Vidyabhusana 1920, p. 58.
[13] Potter and Bhattacharyya 1993, pp. 75–81.
[14] Ganeri 2001a, p. 161.
[15] Peirce 1955, p. 229. See also Landesman 1997.
[16] Peirce 1955, p. 10.
[17] See Sarukkai 2002a on doodling and other discursive strategies in mathematics.
[18] Matilal 2002a, p. 73.
[19] Ibid., p. 80.
[20] For a detailed discussion on debates, see Matilal 1999.
[21] Ibid., p. 45.
[22] Matilal 1999 is a very good source for more on this topic. See also Vidyabhusana 1920.

CHAPTER 3

[1] Gensler 2002, p. 1.
[2] Matilal 1999, p. 1.
[3] Matilal 1985, p. 89. See also Gangopadhyay 1984.
[4] Ibid., p. 30.
[5] Ibid., p. 38.
[6] Matilal 1985, p. 30–37.
[7] Ibid., p. 40.
[8] I have combined Matilal's description with Vidyabhusana's. See Matilal 1999, p. 4 and Vidyabhusana 1920, p. 61.
[9] Matilal 1999, p. 6.
[10] See Hayes 1988.
[11] Matilal 1999, p. 96.
[12] Bharadwaja 1990, p. 11.
[13] Ibid., p. 19.
[14] Hayes 1988, p. 111.
[15] Ibid., p. 154.
[16] Matilal 1999, p. 111.
[17] Prasad 2002, p. 90. See also Chinchore 1989.
[18] Ibid., p. 51.
[19] Ibid., p. 55.
[20] The following definitions and examples are drawn from both Matilal 1999 and Prasad 2002.
[21] Prasad 2002, p. 77.

[22] Matilal 1999, pp. 14–18.
[23] For example, see Matilal 1999 and Bhattacharyya 1987. See also Ganeri 2001b.
[24] Mohanty 1992, pp. 100–132.
[25] Ibid., pp. 117–118.
[26] Ibid., p. 131.
[27] For example, see Staal 1995.
[28] Matilal 1999, p. 15.
[29] Ibid., p. 16.
[30] Ibid., p. 17.
[31] On confirmation problem and its relation to Indian philosophy, see Chakravarthi 2002 and Joerg 1998.
[32] Matilal 1999, p. 12.
[33] Matilal 1985, p. 142.
[34] Chakraborty 1978, p. 222.
[35] Ibid., p. 226. I have replaced the Sanskrit words by their equivalents in the five definitions given here.
[36] Phillips 2002, p. 8.
[37] Ganeri 2001a, p. 157.
[38] Ibid., p. 151.
[39] Matilal 1999, pp. 45–46.
[40] Bhardwaja 1990, p. 74.
[41] Matilal 1999, p. 46.
[42] Vidyabhusana 1920, p. 61.
[43] Bharadwaja 1990, p. 62.
[44] Ganeri 2001a, p. 155. See also Phillips 1997, p. 66, where he notes that Śrīharṣa gives more types.
[45] Ganeri 2001a, p. 158.
[46] Phillips 1997, p. 152.
[47] Ibid., p. 159.
[48] Phillips 2002, p. 14.
[49] Ibid., pp. 16–19.
[50] Ibid., p. 13.
[51] Vidyabhusana 1920, p. 63.
[52] Also see Bharadwaja 1990, p. 30.
[53] Vidyabhusana 1920, pp. 290–291.
[54] Ibid., p. 296.
[55] Matilal 1999, pp. 9–10, pp. 117–125.
[56] Ibid., p. 125.
[57] Phillips 1997, p. 63.
[58] Matilal 1985, p. 166.
[59] Ibid., p. 181.

[60] Ibid., p. 187.
[61] Ibid., p. 193.
[62] Ibid., p. 195.
[63] Matilal 1999, p. 27.
[64] Ibid., p. 144.
[65] See Arindam Chakrabarti 1997, K. K. Chakrabarti 1978 and Phillips 1997 for discussion on absence.
[66] Matilal 1999, p. 146.

CHAPTER 4

[1] See, for example, Hawking 1988 and Weinberg 1993 for a diatribe against philosophers of science.
[2] See Sarukkai 1995 for a discussion on rituals and knowledge.
[3] I say apparently because some sociologists of science would argue that even in these cases there is solidarity and not necessarily objectivity. For some material on sociology of science, see Knorr-Cetina 1983.
[4] Cohen and Nagel 1972, p. 192.
[5] Trusted 1979, pp. 97–98.
[6] Ibid., p. 104.
[7] Wigner 1960. See also Sarukkai 2005.
[8] Quoted in Kline 1985, p. 216.
[9] See Rotman 1993 and Sarukkai 2002a.
[10] For a critique of deductive logic, see Stove 1986 and Sen 1991.
[11] For a comprehensive overview of induction in Western philosophy, see Chattopadhyaya 1991.
[12] Lipton 1991, p. 6.
[13] Salmon 1966, p. 175.
[14] Ibid., p. 185.
[15] Lipton 1991, p. 14.
[16] We can write this inference as 'If ravens, then black.' This is of the form If p, then q. Contrapositive of this is 'If not-q, then not-p', thus leading to 'If non-black, then non-raven'.
[17] See Chakravarthi 2002 and Joerg 1998.
[18] Lipton 1991, p. 22.
[19] Goodman 1973, chapter 3.
[20] Evans 1957, p. 168.
[21] Ibid., p. 168.
[22] Ibid., p. 171.
[23] Ibid., p. 173.
[24] Ibid., p. 175.

[25] Ibid., pp. 177–178.
[26] See also Trusted 1979.
[27] Trusted 1979, p. 16. See Ladyman 2002 for another interpretation.
[28] Lipton 1991. See also Ruben 1993.
[29] Lipton 1991, p. 26.
[30] Ibid., p. 27.
[31] Ibid., p. 31.
[32] Ibid., p. 32.
[33] Ibid., p. 34.
[34] Ibid., p. 35.
[35] Ibid., p. 35.
[36] Ibid., p. 43.
[37] Ibid., p. 45.
[38] Ibid., p. 57.
[39] Ibid., p. 58.
[40] Ibid., p. 67.
[41] Fraassen 1980. See also Ladyman 2002, pp. 219 and 220.
[42] Rosenberg 2000, p. 28.
[43] Salmon 1998, p. 303.
[44] Ibid., p. 308.
[45] Rosenberg 2000, p. 37.
[46] Ibid., pp. 321–329.
[47] Cohen and Nagel 1972, p. 229.
[48] Ibid., p. 235.
[49] Gorskij 1970, p. 313.
[50] Ibid., p. 238.
[51] Poincare 1952, p. 104.
[52] Gorskij 1970, p. 324.
[53] See Jammer 1961.
[54] Gorskij 1970, p. 345.
[55] See Sarukkai 2004.
[56] Cartwright 1983.
[57] Fraassen 1989.
[58] Rosenberg 2000, p. 31.
[59] See Lange 2000 for discussion on laws and counterfactuals.
[60] Ibid., p. 32.
[61] For example, see Armstrong 1997.

CHAPTER 5

[1] Chandrasekhar 1995, p. 23.
[2] Poincare 1952, p. 104.

[3] Jammer 1999, p. 124.
[4] See Norris 1997.
[5] Eco 1984, p. 26.
[6] Ibid., pp. 213, 214.
[7] Ibid., p. 31.
[8] Peirce 1955, p. 98.
[9] Ibid., p. 99.
[10] Ibid., p. 108.
[11] Ibid., p. 114.
[12] Ibid., p. xii.
[13] Ibid., p. 108.
[14] See Siderits 1991.
[15] Boole 1997, pp. 130–131.
[16] Cassirer 1953. See also Ferrari 2002.
[17] Ferrari 2002, p. 17.
[18] Ihmig 2002.
[19] This is of course a simplified view. The various theories of language in these traditions are quite complex and diverse. Also, the exact meaning of arbitrary needs to be understood here. However, it is clear that in the context in which we can consider words as signs they embody arbitrariness as described in this chapter.
[20] Ferrari 2002, p. 5.
[21] This is so even for those like Boole who thought that symbols once created have fixed meaning. The problem is that meaning in these symbols is not similar to meaning in words. In fact, the potentiality of symbols to take on a variety of roles and meaning is what makes the use of arbitrary symbols so appealing.
[22] For a useful discussion on observation, see Hacking 1983.
[23] Ibid., p. 55.
[24] Rosenberg 2000, p. 78.
[25] See Sarukkai 2004.
[26] Wright 1991, p. 142.
[27] Sarukkai 2002a.
[28] There have been sporadic comments about the explanatory role in Indian logic. Vidyabhusana 1920 describes the example in the five-step process as an explanatory example.
[29] Rosenberg 2000, p. 28.
[30] Hempel 1965, p. 265.
[31] Matilal 1985, p. 60.
[32] Ibid., p. 62.
[33] Ganeri 2001a, p. 31.
[34] Salmon 1998, p. 69.

[35] Ibid., p. 70.
[36] Ibid., p. 69.
[37] Matilal 1999, p. 110.
[38] Salmon 1998, p. 95.
[39] Ibid., p. 128.
[40] Poincare 1952, p. xxii.
[41] van Fraassen 1980, p. 157.

CHAPTER 6

[1] See Chisholm 1966 for a good introduction to the subject.
[2] Matilal 2002a.
[3] Ibid., p. 22.
[4] Ibid., p. 22.
[5] Chisholm 1966, p. 6.
[6] See Audi 1998.
[7] Ibid., p. 130.
[8] Ibid., pp. 130–146.
[9] Mohanty 1992, p. 230.
[10] Ibid., p. 113.
[11] For Gettier's problem in the Indian context, see Matilal 2002a.
[12] Audi 1998, p. 221.
[13] Ibid., p. 223.
[14] Matilal 1999 suggests that *tarka* is the closest to *a priori* in Indian philosophy.
[15] See Sarukkai 2002a.
[16] See Audi 1998 on the nature of scientific knowledge, p. 250.
[17] Ibid.,
[18] Ibid., p. 241.
[19] Mohanty 2002, p. 15.
[20] Mohanty 1992, p. 134.
[21] Ibid., p. 137.
[22] Ibid., p. 148.
[23] Audi 1998, p. 231.
[24] Mohanty 1992, p. 138.
[25] Ibid., p. 140.
[26] Ibid., p. 141.
[27] Hacking 1983.
[28] Mohanty 2002, pp. 24–25.
[29] Bhattacharyya 1987, p. 28.
[30] Ibid., p. 38.
[31] Mohanty 1992, pp. 57–58.

[32] Mohanty 2002, p. 26. See also Matilal 1999, p. 99.
[33] Sarukkai 2003 and 2005.
[34] Bhattacharyya 1987, p. 30.
[35] See Narasimha 2003 for a discussion on the algorithmic character of Indian mathematics.
[36] Mohanty 1992, p. 243.
[37] Matilal 2002b, p. 135, notes that the latter kind of inherence, where twoness inheres in both taken together but not in each, is called the *paryāpti* relation.
[38] Ganeri 2001a, p. 91.
[39] Matilal 2002a, p. 29.
[40] See Mohanty 1992, p. 93.
[41] Matilal 2002a, p. 29.
[42] Bhattacharyya 1987, p. xii.
[43] Matilal 2002a, p. 118.
[44] Ibid., p. 319.
[45] Sarukkai 2002a.
[46] Ibid.,
[47] I have referred to this process as pseudotranslation in Sarukkai 2002a.
[48] Wigner 1960.
[49] See Steiner 1998 for more examples.
[50] See Rotman 1993 and Sarukkai 2002a for more on these topics.
[51] Matilal 1999, p. 103.
[52] Probal Dasgupta, personal communication.
[53] For more on the multisemiotic character of scientific discourse, see Sarukkai 2002a.

REFERENCES

Ada, Michael. *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance.* Ithaca: Cornell University Press, 1989.

Alvares, Claude. *Decolonising History.* New York: The Apex Press, 1991.

Armstrong, D. M. *A World of States of Affairs.* Cambridge: Cambridge University Press, 1997.

Audi, Robert. *Epistemology: A Contemporary Introduction to the Theory of Knowledge.* London: Routledge, 1998.

Bharadwaja, Vijay. *Form and Validity in Indian Logic.* Shimla: Indian Institute of Advanced Study. 1990.

Bhattacharyya, Sibajiban. *Doubt, Belief and Knowledge.* New Delhi: Indian Council of Philosophical Research, 1987.

_______. *Language, Testimony and Meaning.* New Delhi: Indian Council of Philosophical Research, 1998.

Boole, G. *Selected Manuscripts on Logic and its Philosophy.* Eds. I. Grattan-Guinness and G. Bornet. Basel: Birkhauser Verlag, 1997.

Cartwright, Nancy. *How the Laws of Physics Lie.* Oxford: Clarendon, 1983.

Cassirer, E. *The Philosophy of Symbolic Forms, Vol I: Language.* New Haven: Yale University Press, 1953.

Chakrabarti, Arindam. *Denying Existence: The Logic, Epistemology and Pragmatics of Negative Existentials and Fictional Discourse.* Dordrecht: Kluwer, 1997.

Chakrabarti, K. K. "The Nyaya-Vaisesika Theory of Negative Entities". *Journal of Indian Philosophy.* 6 (1978): 129–144.

Chakraborty, Krishna. "Definitions of Vyapti (Pervasion) in Navyanyaya: A Critical Survey". *Journal of Indian Philosophy.* 5 (1978): 209–236.

Chandrasekhar, S. *Newton's Principia for the Common Reader.* Oxford: Clarendon, 1995.

Chattopadhyaya, D. P. *Induction, Probability and Skepticism.* Stony Brook: State University of New York, 1991.

_______. *Interdisciplinary Studies in Science, Technology, Philosophy and Culture.* Delhi: PHISPC, 1996.

Chinchore, Mangala, R. *Dharmakirti's Theory of Hetu-Centricity of Anumana.* Delhi: Motilal Banarasidass, 1989.

Chisholm, Roderick. *Theory of Knowledge.* New Jersey: Prentice-Hall, 1966.

Cohen, Morris and Ernest Nagel. *An Introduction to Logic and Scientific Method.* Delhi: Allied Publishers, 1972.

Eco, Umberto. *Semiotics and the Philosophy of Language.* London: Macmillan Press, 1984.

Evans, Luther D., W. S. Gamertsfelder and A. F. Nelson. *Elements of Logic.* Iowa: Wm. C. Brown Company, 1957.

Ferrari, M. "The Concept of Symbol from Leibniz to Cassirer". In *Symbol and Physical Knowledge: On the Conceptual Structure of Physics.* Eds. M. Ferrari and I.O. Stamatescu. Berlin: Springer-Verlag, 2002.

Gadamer, Hans-Georg. *The Beginning of Knowledge.* Trans. R. Coltman. New York: Continuum, 2001.

Ganeri, Jonardon. *Philosophy in Classical India.* London: Routledge, 2001a.

_______. (ed). *Indian Logic: A Reader.* Surrey: Curzon Press, 2001b.

Gangopadhyay, M. K. *Indian Logic in Its Sources: On Validity of Inference.* New Delhi: Munshiram Manoharlal, 1984.

Gensler, Harry J. *Introduction to Logic.* London: Routledge, 2002.

Goodman, Nelson. *Fact, Fiction and Forecast.* 3rd Edition. New York: The Bobbs-Merril Co. Inc., 1973.

Gorskij, D. P. "On the Types of Definition and Their Importance for Science". In *Problems of the Logic of Scientific Knowledge.* Ed. P. V. Tavanec. Dordrecht: Reidel Publishing Company, 1970.

Hacking, Ian. *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science.* New York: Cambridge University Press, 1983.

Hawking, Stephen. *A Brief History of Time: From the Big Bang to Black Holes.* New York: Bantam Books, 1988.

Hayes, Richard. *Dignāga on the Interpretation of Signs.* Dordrecht: Kluwer, 1988.

Hempel, Carl G. *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science.* New York: The Free Press, 1965.

Ihmig, Karl-Norbert. "The Symbol in the Theory of Science". *Symbol and Physical Knowledge: On the Conceptual Structure of Physics.* Eds. M. Ferrari and I.O. Stamatescu. Berlin: Springer-Verlag, 2002.

Jammer, Max. *Concepts of Mass.* Cambridge: Harvard University Press, 1961.

_______. *Concepts of Force.* New York: Dover, 1999.

Kline, Morris. *Mathematics and the Search for Knowledge.* New York: Oxford University Press, 1985.

Knorr-Cetina, K. D., and M. Mulkay (eds). *Science Observed: Perspectives on the Social Study of Science.* Beverly Hills: Sage, 1983.

Ladyman, James. *Understanding Philosophy of Science.* London: Routledge, 2002.

Landesman, Charles. *An Introduction to Epistemology.* Oxford: Blackwell, 1997.

Lange, Marc. *Natural Laws in Scientific Practice.* Oxford: Oxford University Press, 2000.

Lipton, Peter. *Inference to the Best Explanation.* London: Routledge, 1991.

Matilal, Bimal. K. *Logic, Language and Reality: Indian Philosophy and Contemporary Issues.* Delhi: Motilal Banarsidass, 1985.

_______. *The Word and the World: India's Contribution to the Study of Language.* Delhi: Oxford University Press, 1990.

_______. *The Character of Logic in India.* Eds. J. Ganeri and H. Tiwari. Delhi: Oxford University Press, 1999.

_______. *Perception: An Essay on Classical Indian Theories of Knowledge.* Delhi: Oxford University Press, 2002a.

_______. *Mind, Language and World.* Ed. Jonardon Ganeri. Delhi: Oxford University Press, 2002b.

Mohanty, J. N. *Gangesa's Theory of Truth.* Santiniketan: Centre of Advanced Study in Philosophy, 1966.

_______. *Reason and Tradition in Indian Thought: An Essay on the Nature of Indian Philosophical Thinking.* Oxford: Clarendon Press, 1992.

_______. *Essays on Indian Philosophy: Traditional and Modern.* Ed. P. Bilimoria. Delhi: Oxford University Press, 1993.

_______. *Classical Indian Philosophy.* Delhi: Oxford University Press, 2002.

Narasimha, Roddam. "Axiomatism and Computational Positivism". *Economic and Political Weekly.* 38 (2003): 3650–3656.

Norris, Christopher. *Against Relativism: Philosophy of Science, Deconstruction and Critical Theory.* Oxford: Blackwell, 1997.

Oldroyd, David. *The Arch of Knowledge: An Introductory Study of the History of the Philosophy and Methodology of Science.* New York: Methuen, 1986.

Peirce, C. S. *Philosophical Writings of Peirce.* Ed. Justus Buchler. New York: Dover Publications, 1955.

Phillips, Stephen and Ramanuja Tatacharya. *Gangesa on the Upadhi, The "Inferential Undercutting Condition".* New Delhi: Indian Council of Philosophical Research, 2002.

Phillips, Stephen. H. *Classical Indian Metaphysics.* Delhi: Motilal Banarasidass, 1997.

Poincare, H. *Science and Hypothesis.* New York: Dover, 1952.

Potter, Karl H and S. Bhattacharyya. (eds). *Encyclopedia of Indian Philosophies: Vol VI (Indian Philosophical Analysis Nyaya-Vaisesika from Gangesa to Raghunatha Siromani).* Delhi: Motilal Banarasidass, 1993.

Potter, Karl H., (ed). *Encyclopedia of Indian Philosophies: Vol II (The Tradition of Nyaya-Vaisesika up to Gangesa).* Delhi: Motilal Banarasidass, 1977.

Prasad, Rajendra. *Dharmakirti's Theory of Inference: Revaluation and Reconstruction.* Delhi: Oxford University Press, 2002.

Ram-Prasad, Chakravarthi. "A Comparative Treatment of the Paradox of Confirmation". *Journal of Indian Philosophy.* 30 (2002): 339–358.

Rosenberg, Alex. *Philosophy of Science: A Contemporary Introduction.* London: Routledge, 2000.

Rotman, Brian. *Ad Infinitum: The Ghost in Turing's Machine.* Stanford: Stanford University Press, 1993.

Ruben, David-Hillel. (ed). *Explanation.* New York: Oxford University Press, 1993.

Salmon, Wesley. "The Foundations of Scientific Inference" in *Mind*

and Cosmos: Essays in Contemporary Science and Philosophy. Pittsburgh: University of Pittsburgh Press, 1966.

_______. *Causality and Explanation.* New York: Oxford University Press, 1998.

Sarukkai, Sundar. "Mathematization of the Human Sciences – Epistemological Sanskritization?" *Economic and Political Weekly.* 30 (1995): 3357–3360.

_______. *Translating the World: Science and Language.* Lanham: University Press of America, 2002a.

_______. "Interpreting Scientific Terms Across Traditions". *Sandhan,* II (2002b) : 57–72.

_______. "Applying Mathematics: The Paradoxical Relation between Mathematics, Language and Reality". *Economic and Political Weekly.* 38 (2003): 3662–3670.

_______. *Philosophy of Symmetry.* Shimla: Indian Institute of Advanced Study, 2004.

_______. "Revisiting the 'Unreasonable Effectiveness' of Mathematics". *Current Science.* 88 (2005): 414–423.

Sen, Pranab Kumar. *Reference and Truth.* Delhi: Indian Council of Philosophical Research, 1991.

Siderits, Mark. *Indian Philosophy of Language.* Dordrecht: Kluwer, 1991.

Somerville, James. *The Epistemological Significance of the Interrogative.* Hampshire: Ashgate, 2002.

Staal, J. F. *Universals: Studies in Indian Logic and Linguistics.* Chicago: The University of Chicago Press, 1988.

_______. "The Sanskrit of Science". *Journal of Indian Philosophy.* 23 (1995): 73–127.

Steiner, Mark. *The Applicability of Mathematics as a Philosophical Problem.* Cambridge: Harvard University Press, 1998.

Stove, D. C. *The Rationality of Induction.* Oxford: Clarendon Press, 1986.

Trusted, Jennifer. *The Logic of Scientific Inference: An Introduction.* London: The Macmillan Press, 1979.

Tuske, Joerg. "Dinnaga and the Raven Paradox". *Journal of Indian Philosophy.* 26 (1998): 387–403.

Van Fraassen, B. C. *The Scientific Image.* Oxford: Clarendon Press, 1980.

_______. *Laws and Symmetry.* Oxford: Clarendon, 1989.

Vidyabhusana, Satis C. *A History of Indian Logic: Ancient, Mediaeval and Modern Schools.* Calcutta: Motilal Banarasidass, 1920.

Weinberg, Steven. *Dreams of a Final Theory.* London: Hutchinson Radius, 1993.

Wigner, Eugene P. "The Unreasonable Effectiveness of Mathematics in the Natural Sciences". *Communication of Pure and Applied Mathematics.* 13 (1960).

Wright, John. *Science and the Theory of Rationality.* Aldershot: Avebury, 1991.

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